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Current Biofuel Policies: A comparative assessment of their coherence with sustainability goals and an evaluation of existing gaps

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Abstract

This dissertation was written as part of the MSc in Bioeconomy: Biotechnology and Law at the International Hellenic University.

Over the last few decades, after the emergence of biofuels at commercial scale in the 1970s, several policies, at domestic or international level, have promoted these alternative fuels, citing mainly three supporting reasons: their potential to fight energy insecurity, ability to alleviate climate change through decreasing carbon dioxide in the atmosphere -compared to conventional fuels- and capacity to promote agriculture and rural development. But, ever since the beginning of their expansion, it became clear that biofuels are not as sustainable as originally thought. And since policies and national legislative frameworks are the main instruments guiding biofuels' development, the present dissertation aims to focus on answering the question whether current biofuel policies are efficient in ensuring sustainability, while promoting biofuels. If this is found not to be the case, then an attempt will be made in order to examine the relative existing gaps, to discuss the potential conflicting interests and ultimately to proceed with recommending adequate alterations in legislations. Finally, this dissertation will touch upon related ethical dimensions, which could provide some insightful considerations for upcoming biofuel legislations.

Keywords: Biofuels, sustainability, policies, environmental ethics

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Preface

Modern societies, mainly due to overpopulation and intense industrial activity, are currently having particularly high needs for food and energy. At the same time, anthropogenic activities are increasingly burdening the -already deeply affected by previously caused pollution- environment. Humanity is facing unprecedented challenges and governments are striving to manage the current situation. How should they formulate policies and what legislative measures are the most appropriate? It is easy to understand the complex role of laws and policies when trying to regulate contemporary international challenges, especially in an era of intense technological activity, in which novel technologies are emerging to address the most burning issues.

The answer to these pressing global challenges seems to be found through interdisciplinary approaches. This is essentially what led me to enroll to *MSc in Bioeconomy: Biotechnology and Law,* and what eventually led me to investigate this dissertation's subject: *biofuels.* Biofuels, are found in the center of the abovementioned debates, being perceived as a solution to energy sufficiency and security concerns in the times of augmented energy demands, being promoted as an amelioration to conventional fuels in terms of carbon dioxide emissions, and ultimately constituting a filed in which a plethora of technological advancements are emerging and which policies are attempting to regulate. The main question in this dissertation revolves around whether these biofuels are truly environmentally, economically, and socially sustainable, mainly by approaching the relevant legal regulations, as they are the ones that promote their spread. Environmental ethics' issues are also raised, given that biofuels constitute a relatively new area in which legal regulation is insufficient, and in that sense, ethical approaches could provide valuable insights and potentially guidelines for upcoming legislations in the biofuels' context.

Contents

List of Abbreviations

BTC	Biodiesel Tax Credit
CAP	Common Agricultural Policy
CO2	Carbon Dioxide
EPA	U.S. Environmental Protection Agency
EU	European Union
FFVs	Flexible Fuel Vehicles
FQD	Fuel Quality Directive
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GM	Genetically Modified
HVO	Hydrotreated Vegetable Oil
ICESCR	International Covenant on Economic, Social, Cultural Rights
iLUC	Indirect Land Use Change
IRENA	International Renewable Energy Agency
NGOs	Non-Governmental Organizations
R & D	Research and Development
RED	Renewable Energy Directive
RFS	Renewable Fuels Standard
SDGs	Sustainable Development Goals
SCP	Sustainable Consumption & Production
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
USA/ US	United States of America
WTO	World Trade Organization

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Chapter 1: Introduction

Our era is characterized by a plethora of global challenges threatening the future of the Earth. Climate change, population growth, the upcoming exhaustion of natural resources, energy and food insecurity, poverty and inequality are some of the current burning issues seeking to be solved. Constantly increasing population over the last decades along with an unprecedented rate of industrialization -which continues to rise especially in developing countries- have led to elevated energy needs, a challenge which current societies are striving to handle. Energy demand has been covered, till the present day, primarily with fossil fuels and experts estimated in 2009 that over *135 billion tonnes*[1] of oil have been extracted from the Earth since 1850 – the date that marks "the beginning of oil industry"; however, their finite nature is a proof that modern societies can no longer exclusively depend on them as the sole energy source.

Besides energy security concerns, continued fossil fuel *overuse* has caused an increase in greenhouse gas (GHG) emissions in the atmosphere, a situation which contributes to climate change. With global warming being a disastrous reality, already leading to hazardous effects that we experience more frequently daily, and fossil fuels expected to be depleted within the next forty years[2],[3] scientific research has intensified and relevant efforts now aim at the development of alternative and renewable fuels which will ensure sustainability and meet imminent -augmented- energy needs. International organizations and governments, on their part, introduce policies promoting renewable energy (among which solar, wind, biofuels), in an effort to reserve affordable, efficient, environmentally sustainable and equitably distributed energy, and, at the same time, fulfill their ambition to reduce their country's (or member states') contribution to the carbon emissions into the atmosphere; in this attempt, the shift to renewables has been considered as the most suitable pathway.

Biofuels have been perceived as a promising and pioneering solution to safeguard energy security and reduce the dependance on fossil fuels, but also as a means to reduce the GHG emissions problem, since they have been found to be carbon neutral under specific circumstances; this happens when the carbon dioxide (CO2) emitted during

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[1] Jones, J. C. (2009). Technical note: Total amounts of oil produced over the history of the industry. *International Journal of Oil*, *Gas and Coal Technology*, 2(2), 199. https://doi.org/10.1504/ijogct.2009.024887

[2]Shafiee, S., & Topal, E. (2009). When will fossil fuel reserves be diminished? *Energy Policy*, 37(1), 181–189. https://doi.org/10.1016/j.enpol.2008.08.016

[3] BP Statistical Review of World Energy 2016. (2016). Retrieved from http://large.stanford.edu/courses/2016/ph240/stanchi2/docs/bp-2016.pdf

their combustion is equal or less to the atmospheric CO_2 that had been previously used from plants (biofuel feedstock) to photosynthesize. Because of this, it is clear why biofuels have been severely promoted through national – and more rarely international- policies, during the last decades.

1.1 Problem definition, Dissertation Outline and Questions to be answered

Since the 1970s, when commercial biofuel production has begun,[4] several policies, at domestic or international level, have promoted these alternative fuels, citing mainly three supporting reasons: along with the potential to fight energy insecurity and contribute to climate change mitigation, biofuels can also promote agriculture and rural development.[5] But, ever since the beginning of their expansion, it became clear that they are not as sustainable as originally thought. And since policies and national legislative frameworks are the main instruments guiding biofuels development, our aim is to focus on answering the question *whether current biofuel policies are efficient in ensuring sustainability, while promoting biofuels*. If this is found not to be the case, then we will explore the relative gaps existing, discuss the potential conflicting interests and proceed with recommending adequate measures.

In order to explore whether sustainability is promoted in current biofuel policies, our discussion will begin with reviewing the four generations of biofuels in terms of their feedstocks, production technologies and environmental influences. We will proceed with assessing the advantages and disadvantages of these fuels as well as the gaps existing, in an effort to correlate them with sustainability. Then, special attention will be given to the notion of "*sustainability*" and its correlation with "*sustainable development*" and, after elaborating on the three dimensions of sustainability (the environmental, the economical and the social perspective) which act as "*pillars"* or as guiding principles, without the consideration of which true sustainability cannot be achieved, we will move on and discuss the importance of sustainability in biofuels' production and consumption.

At this point and before moving on with examining national policies, we will introduce two additional parameters, which complicate things; a) the paradox of biofuels -the promising solution to global challenges- being merely regulated at national levels currently, and the resulting complications; b) the complexities caused regarding their

[4] Paul, P. E. V., Sangeetha, V., & Deepika, R. G. (2019). Emerging Trends in the Industrial Production of Chemical Products by Microorganisms. *Recent Developments in Applied Microbiology and Biochemistry*, 107–125. https://doi.org/10.1016/b978-0-12-816328-3.00009-x
[5] Moschini, G., Cui, J., & Lapan, H. (2012). Economics of Biofuels: An Overview of Policies, Impacts and Prospects. *Bio-Based and Applied Economics*, 1(3), 269-296. https://doi.org/10.13128/BAE-11143

governance, due to multiple actors with different interests being involved. We will reach the conclusion that the implementation of cross-border environmental objectives seems difficult to be achieved when the existing policies are mainly domestic without international sustainability criteria having been introduced yet, and we will further elaborate on the *(in)existence of a global regime for biofuels*, while presenting other relevant regimes which *can be* -and *are* at the moment- applied regarding biofuels' governance, internationally.

Finally, national policies of the countries leading the biofuels' market (the United States, Brazil and China) will be presented, while particular attention will be given to the supranational policy of the EU; a comparison and assessment will then take place, aiming to identify the existing gaps, assess to what extent biofuels' production is indeed sustainable under the existing status quo, and most importantly conclude whether existing policies and regulatory frameworks respect sustainability principles, and more specifically are designed in a way that leads to a balance between the environmental, the economic and the societal pillars. Recommendations will be ultimately provided, on how true sustainability could be achieved in the biofuels' context.

Chapter 2: Biofuels

In this Chapter, a short description of biofuels, focusing on their technical aspects, will be presented. Besides discussing the feedstock and the relevant technologies used for their production, the main uses of these promising alternative fuels will also be mentioned. Throughout this chapter, problems related to their production and use, which have been identified and have caused concerns among scientists will be highlighted. This information will be necessary in the Chapters that follow, so as to understand how technical aspects of different generations of biofuels could differently affect sustainability and ultimately how policies could, via regulations, promote the biofuels whose production and uses come with the less hazardous effects.

2.1 Biofuels: An introduction

Biofuels, perceived as a promising solution to the continuously increasing demand and upcoming depletion of fossil fuels,[6] are characterized as "rather green energy" since they impact less the environment, compared to conventional fuels, and are a benign alternative to petroleum.

Any fuels produced from organic material (biomass) including plants, animal waste and algae,[7] are classified as biofuels. Energy derived from biofuels is defined as "bioenergy" and it nowadays covers roughly 10% of the energy needs globally.[8] Biofuels include products originating not only from biomass but also its residues, and are mainly produced from photosynthetic organisms such as plants, photosynthetic bacteria and micro-/macro- algae. The primary products of biofuels may be in either gas, liquid, or solid form, however the term is commonly used by scholars in its narrower sense, referring merely to liquid biofuels for transportation.

Biofuels can be primarily divided into two categories: primary and secondary biofuels.[9] *Primary biofuels* include, among others, firewood, wood chips, forest residues and animal waste, and are used untreated, mainly for heating, cooking, or electricity production; they account for a considerable amount of the energy produced in developing countries. Secondary biofuels result after biomass is processed, and can be classified into three

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[6] BP Statistical Review of World Energy 2016. (2016). Retrieved from http://large.stanford.edu/courses/2016/ph240/stanchi2/docs/bp-2016.pdf
[7] Noelle Eckley Selin, & Lehman, C. (2018). biofuel | Definition, Types, & Pros and Cons. In *Encyclopædia Britannica*. Retrieved from https://www.britannica.com/technology/biofuel
[8] Biofuels: 1. What are biofuels? (2007). Retrieved from Greenfacts.org website: https://www.greenfacts.org/en/biofuels/l-2/1-definition.htm#1
[9] Biofuels. (n.d.). Retrieved from Ballotpedia website: https://ballotpedia.org/Biofuels#:~:text=Biofuels%20are%20categorized%20either%20as

generations (in recent years a fourth generation of biofuels has emerged, which includes biofuels produced by synthetic biology).[10] Secondary biofuels are among others: biogas, biodiesel, bioethanol, biomethanol, synthetic biofuels. According to their properties, biofuels can be used as transport fuels either alone or blended with conventional fuels. [11]

Biofuels have -undoubtedly- numerous advantages as their use could remarkably reduce GHG emissions, while significant production at national level, could be proven beneficial for that specific country's economy and could help in the effort to ensure energy sovereignty (along with energy security). Their transportability and easy-to-store feature are also important assets, compared to photovoltaic and wind-power energy sources, which are widely developed but are immovable and not storable. However, biomass sources used to produce biofuels, have to be evaluated bearing in mind the biomass chemical composition, the availability of croplands, the use of pesticides, the cultivation practices, the potential impacts on water resources, soil and biodiversity, as well as an economic and energy balance evaluation has to be conducted,[12] before arguing that biofuels can only have beneficial effects.

2.2 Biofuels' Classifications based on the feedstock used and the relevant production technologies

As mentioned *above*, secondary biofuels are further categorized in four generations, based on the type of raw material and the technologies used for their production. As far as the material used is concerned, first generation biofuels are produced from edible parts of crops -ethanol from sugars and starch, biodiesel from oilseed crops. In the second generation, lignocellulosic biomass from non-food crops is used (such as tree plantations or woody waste from forests) and also inedible parts of food plants.[13] A third generation of biofuels, using algae as their feedstock, has appeared over the last ten years and seemed as the most promising alternative, since in this case, higher yields and a lower GHG footprint were observed, compared to the previous generations'

[10] Moravvej, Z., Makarem, M. A., & Rahimpour, M. R. (2019). The fourth generation of biofuel. *Second and Third Generation of Feedstocks*, 557–597. https://doi.org/10.1016/b978-0-12-815162-4.00020-3
[11] Callegari, A., Bolognesi, S., Cecconet, D., & Capodaglio, A. G. (2019). Production technologies, current role, and future prospects of biofuels feedstocks: A state-of-the-art review. *Critical Reviews in Environmental Science and Technology*, 50(4), 384–436. https://doi.org/10.1080/10643389.
2019.1629801
[12] Naik, S. N., Goud, V. V., Rout, P. K., & Dalai, A. K. (2010). Production of first and second generation biofuels: A comprehensive review. *Renewable and Sustainable Energy Reviews*, 14(2), 578–597. https://doi.org/10.1016/j.rser.2009.10.003
[13] EASAC. (2012). *The current status of biofuels in the European Union, their environmental impacts and future prospects*. Retrieved from https://easac.eu/fileadmin/PDF_s/reports_statements/Easac_12_Biofuels_Complete.pdf

feedstock.[14] An even more promising solution seems to come with the fourth generation of biofuels, which use the tools of novel synthetic biology, however these can only be found at basic research level.[15] *Figure 1* shows the different feedstocks per generation more analytically.

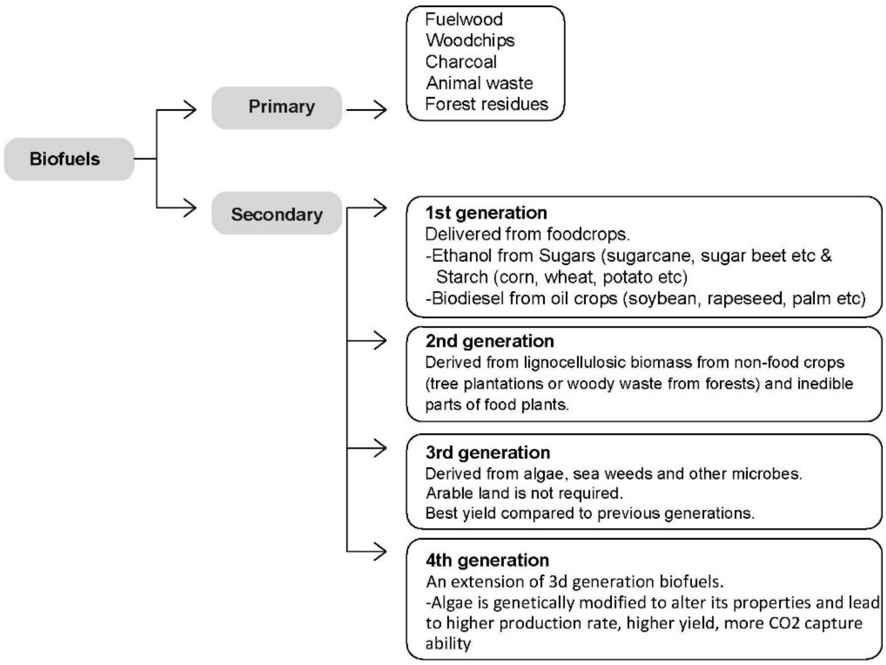

Figure 1: Biofuels' Feedstocks per generation

As we highlighted above, biofuels are divided in four generations according not only to the type of biomass used for their production, but also the relevant production technologies. While first- and second-generation biofuels are currently the only commercially available choice[16], in recent years, important technologies have immerged aiming to produce biofuels more sustainably. Under *Figures 2 and 3*, these different technologies are more thoroughly presented.

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[14] Callegari, A., Bolognesi, S., Cecconet, D., & Capodaglio, A. G. (2019). Production technologies, current role, and future prospects of biofuels feedstocks: A state-of-the-art review. *Critical Reviews in Environmental Science and Technology*, 50(4), 384–436.https://doi.org/10.1080/10643389. 2019.1629801

[15] Aro, E.-M. (2015). From first generation biofuels to advanced solar biofuels. *Ambio*, 45(S1), 24–31. https://doi.org/10.1007/s13280-015-0730-0

[16] Abdullah, B., Syed Muhammad, S. A. F., Shokravi, Z., Ismail, S., Kassim, K. A., Mahmood, A. N., & Aziz, M. M. A. (2019). Fourth generation biofuel: A review on risks and mitigation strategies. *Renewable and Sustainable Energy Reviews*, 107, 37–50. https://doi.org/10.1016/j.rser.2019.02.018

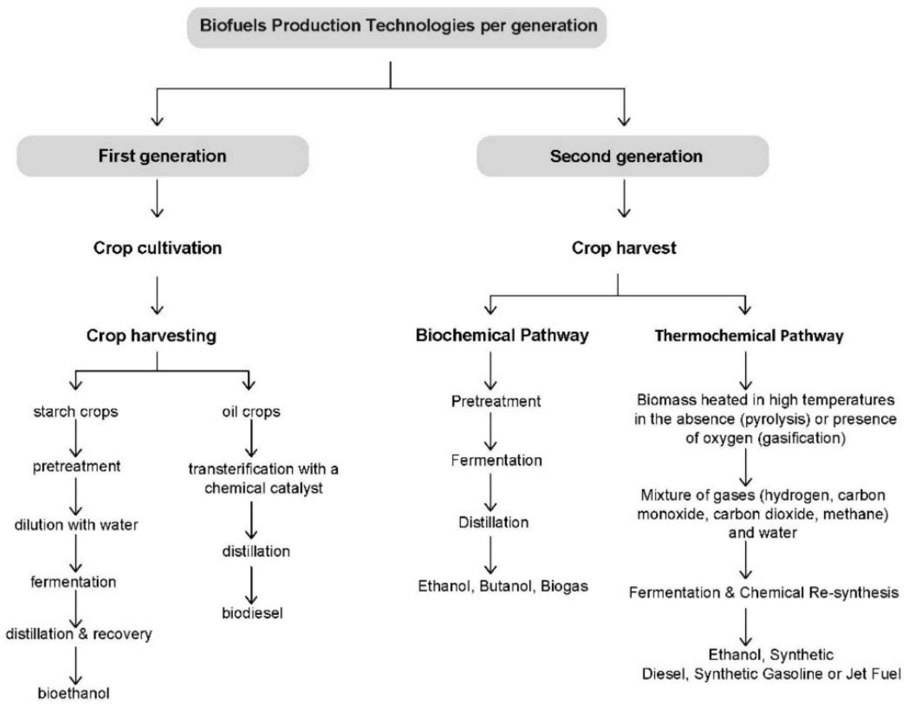

Figure 2: 1st and 2nd generation biofuels technologies

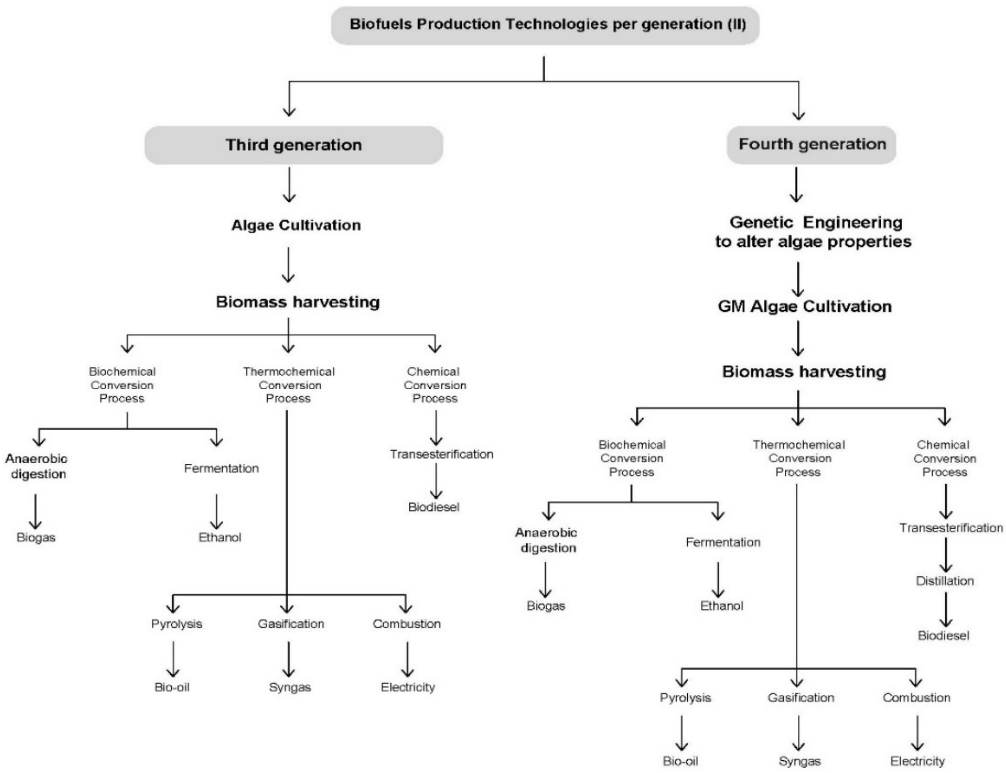

Figure 3: 3d and 4th generation biofuels technologies

2.2.1 First generation of biofuels

First-generation biofuels use as their source *edible biomass*, mainly starch (wheat, corn, potato) and sugars (sugar beet and sugarcane) but also grains, oilseeds and vegetable oils.[17] They were initially promoted in order to decrease the levels of fossil fuels' use and reduce the atmospheric CO2 (plants use carbon dioxide, one of the main GHG, for their growth). However, using edible crops as feedstock soon caused skepticism, especially because of the potential impacts that cultivations for biofuels could have on biodiversity, food supply and cropland use,[18] as well as water sustainability. Moreover, concerns soon arose on whether this generation biofuels are indeed sustainable.

First generation biofuels mainly include ethanol (originating from grains and sugarcane) and biodiesel (made from vegetable oils and animal fats). They are characterized either by their ability to be used in existing alternative vehicles (natural gas vehicles or Flexible Fuel Vehicles (FFVs)) or their ability to be blended with conventional fuels and used in conventional internal combustion engines. First generation biofuels are produced commercially today and are mainly used in transportation.

When it comes to their production process and technologies, and with regards specifically to bioethanol production, it begins with the harvesting of the crops used as a source (for example sugarcane) and then it involves pretreatment, dilution with water and fermentation. After that, distillation takes place in two steps, so as to increase the content of the ethanol in the product, followed by dehydration aiming to produce anhydrous ethanol (basically 100% ethanol). Finally, ethanol is denaturated with petroleum.[19] Ethanol can be blended mainly with petrol, but also with petroleum diesel. On the other hand, first-generation biodiesel gets produced from vegetable oils and via a transesterification reaction with a chemical catalyst (acid/alkali) or enzyme. This reaction is followed by a distillation process which removes by-products produced during the reaction. Distillation is necessary in order to reduce monoglycerols that could be present in trace concentrations after water washing,[20] but could also be entirely avoided if the biodiesel product is properly handled after transesterification.

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[17] Singh, R., Prakash, A., Balagurumurthy, B., & Bhaskar, T. (2015). Hydrothermal Liquefaction of Biomass. *Recent Advances in Thermo-Chemical Conversion of Biomass*, 269–291. https://doi.org/10.1016/b978-0-444-63289-0.00010-7

[18] Alalwan, H. A., Alminshid, A. H., & Aljaafari, H. A. S. (2019). Promising evolution of biofuel generations. Subject review. *Renewable Energy Focus*, 28, 127–139. https://doi.org/10. 1016/j.ref.2018.12.006

[19] Driving Ethanol. (2007). How Ethanol Is Made Animated Feature [YouTube Video]. Retrieved from https://www.youtube.com/watch?v=59R-NqykoXs&ab_channel=DrivingEthanol

[20] Dutta, K., Daverey, A., & Lin, J.-G. (2014). Evolution retrospective for alternative fuels: First to fourth generation. *Renewable Energy*, 69, 114–122. https://doi.org/10.1016/j.renene.2014.02.044

2.2.2 Second generation of biofuels

Second generation biofuels soon appeared in an attempt to solve the various problems that have been identified as downsides in the first generation. One of the main differences between the two generations is that the feedstock used in the second generation is not biomass destined for food, but lignocellulosic material[21] including by-products (sugarcane bagasse, forest residues, cereal straw), wastes (organic components of domestic waste)[22] but also dedicated feedstocks (short rotation wood crops, purpose-grown grasses) [23]. It is often claimed that second-generation biofuels are carbon neutral or even carbon negative in terms of their impact on CO2 concentrations[24],[25], however, their sustainability is nonetheless questioned.[26]

Theoretically, it should be possible to produce biofuels from by-products and waste with almost no additional land requirements and even with no competition with food production -given the nonedible nature of their raw material. In fact, it was estimated that annual supplies of residues and wastes could have an energy potential of over 100EJ per year.[27] But, when it comes to dedicated second-generation feedstock grown in croplands, concerns arise, since land is still used, “threatening” food and fiber production. However, energy yields are probably higher in this scenario, than they would have been if first-generation feedstock were grown instead.[28]

There are two main alternative processes for the production of second-generation biofuels (from non-edible biomass): a) In the *biochemical pathway*, pretreatment is necessary for the cellulose and hemicellulose to be separated from lignin, followed by enzymatic hydrolysis (saccharification), which is the process in which cellulases are added to hydrolyze pretreated lignocellulosic biomass into fermentable sugars,[29] then

[21] Gomez, L. D., Steele-King, C. G., & McQueen-Mason, S. J. (2008). Sustainable liquid biofuels from biomass: the writing’s on the walls. *New Phytologist*, 178(3), 473–485. https://doi.org/10.1111/j.1469-8137.2008.02422.x

[22] Sims, R. E. H., Mabee, W., Saddler, J. N., & Taylor, M. (2010). An overview of second generation biofuel technologies. *Bioresource Technology*, 101(6), 1570–1580. https://doi.org/10.1016/ j.biortech.2009.11.046

[23] Gent, S., Twedt, M., Gerometta, C., & Almberg, E. (2017). Introduction to Feedstocks. *Theoretical and Applied Aspects of Biomass Torrefaction*, 17–39. https://doi.org/10.1016/b978-0-12-809483-9.00002-6 .

[24] Naik, S. N., Goud, V. V., Rout, P. K., & Dalai, A. K. (2010). Production of first and second generation biofuels: A comprehensive review. *Renewable and Sustainable Energy Reviews*, 14(2), 578–597. https://doi.org/10.1016/j.rser.2009.10.003

[25] Sims, R. E. H., Mabee, W., Saddler, J. N., & Taylor, M. (2010). An overview of second generation biofuel technologies. *Bioresource Technology*, 101(6), 1570–1580. https://doi.org/10.1016/ j.biortech.2009.11.046

[26] Mohr, A., & Raman, S. (2013). Lessons from first generation biofuels and implications for the sustainability appraisal of second generation biofuels. *Energy Policy*, 63, 114–122. https://doi.org/10.1016/j.enpol.2013.08.033

[27] *Potential Contribution of Bioenergy to the World’s Future Energy Demand*. (n.d.). Retrieved from https://www.ieabioenergy.com/wp-content/uploads/2013/10/Potential-Contribution-of-Bioenergy-to-the-Worlds-Future-Energy-Demand.pdf

[28] Sims, R. E. H., Mabee, W., Saddler, J. N., & Taylor, M. (2010). An overview of second generation biofuel technologies. *Bioresource Technology*, 101(6), 1570–1580. https://doi.org/10.1016/ j.biortech.2009.11.046

[29] Fan, Z. (2014). Consolidated Bioprocessing for Ethanol Production. *Biorefineries*, 141–160. https://doi.org/10.1016/b978-0-444-59498-3.00007-5

fermentation and distillation[30],[31]; b) while, in *the thermochemical* alternative, biomass is heated in high temperatures in the absence (pyrolysis) or presence of oxygen (gasification), producing, consequently, a mixture of gases (among which hydrogen, carbon monoxide, carbon dioxide, methane) and water. Fermentation is part of this second process as well, followed by chemical re-synthesis; ultimately, a range of biofuels can be reformed as a result of this pathway, including ethanol, synthetic diesel or aviation fuel.[32]

Second generation biofuels seem to be an improvement to first generation ones, with some of the technologies used for their production seemingly offering significant reductions to GHG emissions.[33] Even though the competition with food production (food - energy conflict) is only relevant in the case of dedicated croplands in this generation (as mentioned above), the most alarming concern in this case appears to be the probability of deforestation being caused.[34]

2.2.3 Third generation of biofuels

In third-generation biofuels, several kinds of microorganisms serve as feedstocks, their common characteristic being that they are cultivated in water (aquatic feedstocks).[35] With microalgae playing a pivotal role, this generation's fuels are being defined in literature as *fuels that are produced from algal biomass*. The distinctive feature of algal biomass, when compared with classical lignocellulosic biomass, is its substantial growth yield.[36] Algae has the potential to be cultivated in numerous different climatic conditions and generally throughout the year, a fact which can lead to larger amounts of biofuel production, compared to previous generations' feedstock.[37] Moreover, it can be adequately grown in salt water and wastewater -otherwise unsuitable for traditional crops

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[30] Dutta, K., Daverey, A., & Lin, J.-G. (2014). Evolution retrospective for alternative fuels: First to fourth generation. *Renewable Energy*, 69, 114–122. https://doi.org/10.1016/j.renene.2014.02.044

[31] Schuck, S. (2014). First- and Second-Generation Biofuel Technologies | Issues Magazine. Retrieved from Issuesmagazine.com.au website: http://www.issuesmagazine.com.au/article/issue-december-2008/first-and-second-generation-biofuel-technologies.html

[32] Sims, R. E. H., Mabee, W., Saddler, J. N., & Taylor, M. (2010). An overview of second generation biofuel technologies. *Bioresource Technology*, 101(6), 1570–1580. https://doi.org/10.1016/j.biortech.2009.11.046

[33] EASAC. (2012). *The current status of biofuels in the European Union, their environmental impacts and future prospects*. Retrieved from https://easac.eu/fileadmin/PDF_s/reports_statements/Easac_12_Biofuels_Complete.pdf

[34]Abdullah, B., Syed Muhammad, S. A. F., Shokravi, Z., Ismail, S., Kassim, K. A., Mahmood, A. N., & Aziz, M. M. A. (2019). Fourth generation biofuel: A review on risks and mitigation strategies. *Renewable and Sustainable Energy Reviews*, 107, 37–50. https://doi.org/10.1016/j.rser.2019.02.018

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[37] Behera, S., Singh, R., Arora, R., Sharma, N. K., Shukla, M., & Kumar, S. (2015). Scope of Algae as Third Generation Biofuels. *Frontiers in Bioengineering and Biotechnology*, 2. https://doi.org/10.3389/fbioe.2014.00090

cultivation[38]- and thus is a more promising alternative, given the upcoming freshwater scarcity.

Third generation biofuels have significant advantages over previous generations biofuels; high biomass yield, high growth rate[39], low cultivation requirements (arable land, freshwater, pesticides are not necessary in this case) and overall avoidance of competition with food, water, and land, as it happens with first- and second- generation biofuels. Furthermore, microalgae has the additional ability to eliminate inorganic nutrients from wastewater and to generate higher quantities of green biomass.[40] Therefore, combining microalgal cultivation with wastewater treatment could be a promising, dual-purpose solution[41], which would ultimately also result in economic and efficient production of microalgal-based biofuels.[42]

Even so, challenges exist in this generation of biofuels as well; cultivation at industrial scale, would mean that large amounts of water would have to be used, hence only some countries would be able to commercially produce this generation's biofuels and only in specific parts in the world;[43] high cost;[44] the fact that biofuels produced from algae are less stable than the ones produced from other sources and thus more likely to degrade (especially at high temperatures).[45]

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[38] Gajraj, R. S., Singh, G. P., & Kumar, A. (2018). Third-Generation Biofuel: Algal Biofuels as a Sustainable Energy Source. *Biofuels: Greenhouse Gas Mitigation and Global Warming*, 307–325. https://doi.org/10.1007/978-81-322-3763-1_17

[39] Lee, R. A., & Lavoie, J.-M. (2013). From first- to third-generation biofuels: Challenges of producing a commodity from a biomass of increasing complexity. *Animal Frontiers*, 3(2), 6–11. https://doi.org/10.2527/af.2013-0010

[40]Alalwan, H. A., Alminshid, A. H., & Aljaafari, H. A. S. (2019). Promising evolution of biofuel generations. Subject review. *Renewable Energy Focus*, 28, 127–139. https://doi.org/10.1016/ j.ref.2018.12.006

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[42] Bharathiraja, B., Chakravarthy, M., Ranjith Kumar, R., Yogendran, D., Yuvaraj, D., Jayamuthunagai, J., … Palani, S. (2015). Aquatic biomass (algae) as a future feed stock for bio-refineries: A review on cultivation, processing and products. *Renewable and Sustainable Energy Reviews*, 47, 634–653. https://doi.org/10.1016/j.rser.2015.03.047

[43] Lee, R. A., & Lavoie, J.-M. (2013). From first- to third-generation biofuels: Challenges of producing a commodity from a biomass of increasing complexity. *Animal Frontiers*, 3(2), 6–11. https://doi.org/10.2527/af.2013-0010

[44]Behera, S., Singh, R., Arora, R., Sharma, N. K., Shukla, M., & Kumar, S. (2015). Scope of Algae as Third Generation Biofuels. *Frontiers in Bioengineering and Biotechnology*, 2. https://doi.org/10.3389/fbioe.2014.00090

[45] Shah, S. H., Raja, I. A., Rizwan, M., Rashid, N., Mahmood, Q., Shah, F. A., & Pervez, A. (2018). Potential of microalgal biodiesel production and its sustainability perspectives in Pakistan. *Renewable and Sustainable Energy Reviews*, 81, 76–92. https://doi.org/10.1016/j.rser.2017.07.044

2.2.4 Fourth generation of biofuels

The fourth generation of biofuels has recently emerged in an attempt to reduce high biofuel costs and as a solution to limited land and water resources.[46] Fourth generation biofuels can be generated by designer photosynthetic microorganisms to produce photobiological solar fuels, by combining photovoltaics and microbial fuel production (electrobiofuels) or by synthetic cell factories or synthetic organelles.[47]Genetically modified microalgae, macroalgae and cyanobacteria are utilized as biomass sources, with the hope to meet the above-mentioned needs. Microalgae and macroalgae are eukaryotes, while cyanobacteria are prokaryotes. Their common characteristic is their adaptability to extreme environmental conditions; salinity, drought, photo-oxidation, osmotic pressure, temperature anaerobiosis, and ultraviolet (UV) radiation.[48]

In this generation, genetic modifications happen in order for the GM organisms to consume more CO2 than the amount emitted in later combustion of the fuel[49], or to achieve higher energy yields and production rates.[50] Moreover, in this generation, and during the conversion processes of algal biomass to biofuels, new advanced technologies are used. However, we should not forget that biofuels produced in these ways can nowadays only be found at research level.

Researchers have recently also started to focus on the environmental advantages of using GM algae such as wastewater treatment by heavy metal bioremediation,[51] CO2 sequestration and assimilation,[52] GHG emission reduction. On the other hand, there are also specialists that have raised concerns regarding the environmental and health risks[53] associated with GM algal biofuel. The environmental impact of cyanobacteria via

[46] Moravvej, Z., Makarem, M. A., & Rahimpour, M. R. (2019). The fourth generation of biofuel. *Second and Third Generation of Feedstocks,* 557–597. https://doi.org/10.1016/b978-0-12-815162-4.00020-3
[47] Aro, E.-M. (2015). From first generation biofuels to advanced solar biofuels. *Ambio*, 45(S1), 24–31. https://doi.org/10.1007/s13280-015-0730-0
[48] Guedes, A. C., Amaro, H. M., & Malcata, F. X. (2011). Microalgae as Sources of Carotenoids. *Marine Drugs*, 9(4), 625–644. https://doi.org/10.3390/md9040625
[49] Abdullah, B., Syed Muhammad, S. A. F., Shokravi, Z., Ismail, S., Kassim, K. A., Mahmood, A. N., & Aziz, M. M. A. (2019). Fourth generation biofuel: A review on risks and mitigation strategies. *Renewable and Sustainable Energy Reviews*, 107, 37–50. https://doi.org/10.1016/j.rser. 2019.02.018
[50] Sikarwar, V. S., Zhao, M., Fennell, P. S., Shah, N., & Anthony, E. J. (2017). Progress in biofuel production from gasification. *Progress in Energy and Combustion Science*, 61, 189–248. https://doi.org/10.1016/j.pecs.2017.04.001
[51]Zeraatkar, A. K., Ahmadzadeh, H., Talebi, A. F., Moheimani, N. R., & McHenry, M. P. (2016). Potential use of algae for heavy metal bioremediation, a critical review. *Journal of Environmental Management*, 181, 817–831. https://doi.org/10.1016/j.jenvman.2016.06.059
[52]Zhu, B., Chen, G., Cao, X., & Wei, D. (2017). Molecular characterization of CO2 sequestration and assimilation in microalgae and its biotechnological applications. *Bioresource Technology*, 244, 1207–1215. https://doi.org/10.1016/j.biortech.2017.05.199
[53] OECD. (2015). BIOSAFETY AND THE ENVIRONMENTAL USES OF MICRO-ORGANISMS: CONFERENCE PROCEEDINGS © OECD 2015 II.4.The need and risks of using transgenic microalgae for the production of food, feed, chemicals and fuels. Retrieved from https://www.oecd-ilibrary.org/the-need-and-risks-of-using-transgenic-micro-algae-for-the-production-of-food-feed-chemicals-and-fuels_5js7pn979x31.pdf?itemId=%2Fcontent%2Fcomponent%2F9789264213562-8-en&mimeType=pdf

toxin production[54] and coastal blooms formation, and the possibility that GM algae and cyanobacteria could cause environmental harm have been discussed by scientists.[55]

Third and fourth generation biofuels technologies

Algae-based biofuels, in the third and fourth generation, result after algae has been cultivated, harvested, and then converted to biofuels via oil extraction. For cultivation, either open pond systems or photobioreactors are used,[56] with the latter gaining attention over the last few years, as they are easier to control and less prone to contamination, hence resulting in higher production.[57] The algal biomass harvesting can happen with various techniques,[58] and, it can be converted to biofuels by either biochemical or thermochemical conversion process, like previous generation biofuels mentioned *above*. Whether the thermochemical or biochemical pathway will be used, and which type of microalgae will be cultivated, depends on the type of biofuel aimed to be produced. Especially for fourth generation biomass, microorganisms used, prior to cultivation, are genetically modified aiming at quicker production rates, higher yields and an increased ability to capture CO2 from the atmosphere during their growth.[59]

2.3 Biofuel Applications

Biofuels are mainly destined to be used in transportation[60] and have already gained a significant share in the transportation sector's energy consumption. In the U.S, in 2019, biofuels' consumption reached at 5% of the total energy consumption in transportation, (4% ethanol and 1% biodiesel).[61] In the EU, biofuels accounted for 7.1 percent of energy

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[54] Claxton, L. D. (2015). The history, genotoxicity and carcinogenicity of carbon-based fuels and their emissions: Part 4 – Alternative fuels. *Mutation Research/Reviews in Mutation Research*, 763, 86–102. https://doi.org/10.1016/j.mrrev.2014.06.003

[55] Abdullah, B., Syed Muhammad, S. A. F., Shokravi, Z., Ismail, S., Kassim, K. A., Mahmood, A. N., & Aziz, M. M. A. (2019). Fourth generation biofuel: A review on risks and mitigation strategies. *Renewable and Sustainable Energy Reviews*, 107, 37–50. https://doi.org/10.1016/j.rser. 2019.02.018

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[57] Dutta, K., Daverey, A., & Lin, J.-G. (2014). Evolution retrospective for alternative fuels: First to fourth generation. *Renewable Energy*, 69, 114–122. https://doi.org/10.1016/j.renene.2014.02.044

[58] Zhu, L., Li, Z., & Hiltunen, E. (2018). Microalgae Chlorella vulgaris biomass harvesting by natural flocculant: effects on biomass sedimentation, spent medium recycling and lipid extraction. *Biotechnology for Biofuels*, 11(1). https://doi.org/10.1186/s13068-018-1183-z

[59] Sikarwar, V. S., Zhao, M., Fennell, P. S., Shah, N., & Anthony, E. J. (2017). Progress in biofuel production from gasification. *Progress in Energy and Combustion Science*, 61, 189–248. https://doi.org/10.1016/j.pecs.2017.04.001

[60] Brito Cruz, C. H., Souza, G. M., & Barbosa Cortez, L. A. (2014). Biofuels for Transport. *Future Energy*, 215–244. https://doi.org/10.1016/b978-0-08-099424-6.00011-9

[61] Use of energy for transportation - U.S. Energy Information Administration (EIA). (2020). Retrieved from Eia.gov website: https://www.eia.gov/energyexplained/use-of-energy/transportation.php

use in transport in 2018 and were expected to increase to 7.3 percent in 2019.[62] Biofuels' use in transportation is fundamental for the EU to achieve the target to reduce its carbon footprint, lower GHG emissions and achieve domestic energy security.

At this point we should focus on the fact that biofuels' use in the transport sector not only is the answer to the constantly increasing demand for fuels, which cannot be met by conventional petroleum-fuels due to their finite nature, but could also be the solution to the uneven distribution of fossil fuels; certain regions in the world have a high concentration of reserves, while others are currently dependent on imports of crude petroleum, which makes them vulnerable to oil price changes and could even lead to a domestic energy crisis. Because of this, it is fundamental to produce alternative fuels from locally available resources, such as alcohol, biodiesel, vegetable oils.[63]

Even though use for transportation purposes has gained the majority of attention, it is equally important to highlight the fact that a great part of energy consumption and carbon emissions come from building operations as well.[64] To alleviate the environmental impact of building operations, among others, alternatives to dwindling fossils fuels must be considered. Bioheat oil[65] has already emerged in the US, as a sustainable alternative, and biofuels for heating are gaining in general more popularity around the globe, with certain regions already using renewable fuels for heating.

Besides being used in the transportation sector and their potential for heating purposes, biofuels can also be used for power generation[66] and their ability to clean oil spills has also been researched.[67]

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[62] EU-28: Biofuels Annual | Data & Analysis | USDA Foreign Agricultural Service. (2020). Retrieved from Usda.gov website: https://www.fas.usda.gov/data/eu-28-biofuels-annual-1.

[63] Agarwal, A. K. (2007). Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines. *Progress in Energy and Combustion Science*, 33(3), 233–271. https://doi.org/10.1016/j.pecs.2006.08.003

[64]Fenner, A. E., Kibert, C. J., Woo, J., Morque, S., Razkenari, M., Hakim, H., & Lu, X. (2018). The carbon footprint of buildings: A review of methodologies and applications. *Renewable and Sustainable Energy Reviews*, 94, 1142–1152. https://doi.org/10.1016/j.rser.2018.07.012

[65] https://mybioheat.com

[66] D´Agosto, M. de A., Vieira da Silva, M. A., de Oliveira, C. M., Franca, L. S., da Costa Marques, L. G., Soares Murta, A. L., & de Freitas, M. A. V. (2015). Evaluating the potential of the use of biodiesel for power generation in Brazil. *Renewable and Sustainable Energy Reviews*, 43, 807–817. https://doi.org/10.1016/j.rser.2014.11.055

[67] Miller, N. J., & Mudge, S. M. (1997). The effect of biodiesel on the rate of removal and weathering characteristics of crude oil within artificial sand columns. *Spill Science & Technology Bulletin*, 4(1), 17–33. https://doi.org/10.1016/s1353-2561(97)00030-3

Chapter 3: Sustainable development and correlation with biofuels

Following the short description related to the technical aspect of biofuels, *under Chapter 2* and having already highlighted the main concerns surrounding their production processes, we now continue our discussion, focusing on the concept of sustainability, the key principles surrounding this idea, and its role in the biofuels' context. This information will then be used, in following chapters, to assess the sustainability of current biofuels policies and regulatory frameworks around the globe as well as to propose suitable solutions.

3.1 Defining Sustainability

Sustainability, a word more than frequently encountered in environmental conversations, a concept applied to business, energy, and agriculture -among other fields, is something that we still struggle to define. What does it mean for something to be sustainable?[68]

Sustainability has a long history. Even before the Neolithic Agricultural Revolution, when the big swap from a hunting and gathering lifestyle to agricultural settlements took place, humans have consumed environmental resources rather than replenished them and ultimately worried for the future adequacy of raw material. Humans in this distant era understood the transient nature of some resources, that soil, for example, had a maximum fertility which could be depleted. Even though the theoretical concept of "sustainable living", was not established back then, they also understood that changing their habits would be the only way for nature to sustain them. Either by moving to new places, after having exploited the local resources, or by further changing their existing environment, they strived for their practices and themselves to be sustained. However, in a plethora of circumstances, societies collapsed due to their inhabitants' unsustainable practices.[69]

In the modern world, we have become more aware of the damages caused by human activities and the related uncertainty for the future of natural deposits. Distress over natural elements depleting while the Earth's population is over-growing have been expressed even since the Renaissance.[70] The concept of sustainability -Nachhaltigkeit in German- was firstly introduced by Hans Carl von Carlowitz in the 18th century.

[68] A Brief History of Sustainability – The World Energy Foundation. (n.d.). Retrieved from the world energy foundation website: https://theworldenergyfoundation.org/a-brief-history-of-sustainability/.
[69] Mason, M. (2014). What is sustainability and why is it important? Retrieved from Environmentalscience.org website: https://www.environmentalscience.org/sustainability
[70] Du Pisani, J. A. (2006). Sustainable development – historical roots of the concept. *Environmental Sciences*, 3(2), 83–96. https://doi.org/10.1080/15693430600688831

Nowadays considered the father of sustainable yield forestry, he was the first to recognize that we should not cut down more trees than those needed to replace them- a basic sustainability principle.[71] So, originally, sustainability required that humans only exploit natural renewable resources in a way that they would not be exhausted, and thus that the community could continue to rely on them in the long term.

However, it was not until the 20th century that environmental damage was fully understood. Pollution, deforestation, fossil fuels' depletion led to a growing awareness about the environment and whether anthropogenic activities, and we humans, are a threat, harming our own ecosystem. Nowadays sustainability is a global concept and the term itself is broad and difficult to define precisely.[72] A simple definition could be that "sustainability" is the ability to exist perpetually. In the 21st century, sustainability is also viewed as an "*equilibrium in the process of interaction between humankind and the biosphere*" *(Ben-Eli, 2015*), an equilibrium which will allow mankind development to express its full potential without causing irreversible adverse effects on the environment upon which it depends.[73]

As complete as the aforementioned definition may appear, it seems that different people, in different contexts, define sustainability differently. Elements such as intergenerational equity (and intra-generational equity), have come into surface and have been viewed as necessary elements to define sustainability, especially after the Brundtland Commission introduced the iconic definition of sustainable development as being the *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs".*[74]

At this point we should pinpoint the fact that in academic literature we encounter two terms, "sustainability" and "sustainable development", which are often intertwined and may seem difficult to tease apart. According to UNESCO, their difference is that "*sustainability is the long-term goal, while sustainable development refers to the many processes and pathways used as the means to achieve it*".[75] Even though experts have

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[71] ExplainityChannel. (2012). Sustainability explained [YouTube Video]. Retrieved from https://www.youtube.com/watch?v=_5r4loXPyx8&ab_channel=explainitychannel
[72] Mohin, T. (2009). Less is More Obvious: Why Sustainability Is So Hard To Define | Greenbiz. Retrieved from www.greenbiz.com website: https://www.greenbiz.com/article/less-more-obvious-why-sustainability-so-hard-define#:~:text=The%20official%20definition%20from%2025
[73] Ben-Eli, M. (2015). Sustainability:Definition and Five Core Principles, A New Framework. Retrieved from https://www.sustainabilitylabs.org/assets/img/SL5CorePrinciples.pdf
[74] Report of the World Commission on Environment and Development : (1987). *United Nations Digital Library System*. Retrieved from https://digitallibrary.un.org/record/139811?ln=en
[75] UNESCO. (2015). Sustainable Development. Retrieved from UNESCO website: https://en.unesco.org/themes/education-sustainable-development/what-is-esd/sd#:~:text=Sustainability%20is%20often%20thought%20of

elaborated on the different meanings of these two terms,[76] after the appearance of UN's Sustainable Development Goals (SDGs) in 2015,[77] "sustainable development" is frequently encountered and alternatively used with "sustainability".

In the end, what is important to always bear in mind, regarding sustainability, is that the transformation to a sustainable global environment, economy and society is one of the most challenging tasks humanity is faced with in the modern era.[78]

3.1.1 The Three Pillars of Sustainability

Sustainability, as analyzed above, can be defined in various ways. Over the years it became obvious that sustainability is composed of different elements and in 2005, the World Summit on Social Development pointed out the three central components of sustainability (the economic, environmental and societal component) and characterized them as "interdependent and mutually reinforcing".[79] These interconnecting "pillars" (this term if frequently encountered in literature) are frequently depicted as three intersecting circles in a Venn diagram, where environment, economy and society each are presented with a circle and sustainability is placed in their intersection.[80] (See *Figure 4*)

[76] Many experts in the field have disagreed with the term "sustainable development", stating that these two cannot be connected. They based their arguments on the fact that the term carried a historical meaning, rooted in Western colonial capitalist narratives, and was connected to developing nations. Because of that, and because of the economic-centered nature of "development", a plethora of socio-ecological abuses had been reported throughout its history. In this sense, they supported that such a notion of sustainability would be a barrier and detrimental in the effort to achieve it Sustainability, on the contrary, seemed to be a better term to use. It might appear vague and there is a constant need and effort to define it, but it carries far less historical baggage. /
Purvis, B., Mao, Y., & Robinson, D. (2018). Three pillars of sustainability: in search of conceptual origins. *Sustainability Science*, 14(3), 681–695. https://doi.org/10.1007/s11625-018-0627-5

[77] United Nations. (2018). About the Sustainable Development Goals. Retrieved from United Nations Sustainable Development website: https://www.un.org/sustainabledevelopment/sustainable-development-goals/

[78] Hak, T., Janoušková, S., & Moldan, B. (2015). Sustainable development goals: A need for relevant indicators. *Ecological Indicators*, 60, 565–573. https://doi.org/10.1016/j.ecolind.2015.08.003

[79] World Summit Outcome, Resolution adopted by the General Assembly on 16 September 2005. (2005). Retrieved from https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_60_1.pdf

[80] Purvis, B., Mao, Y., & Robinson, D. (2018). Three pillars of sustainability: in search of conceptual origins. *Sustainability Science*, 14(3), 681–695. https://doi.org/10.1007/s11625-018-0627-5

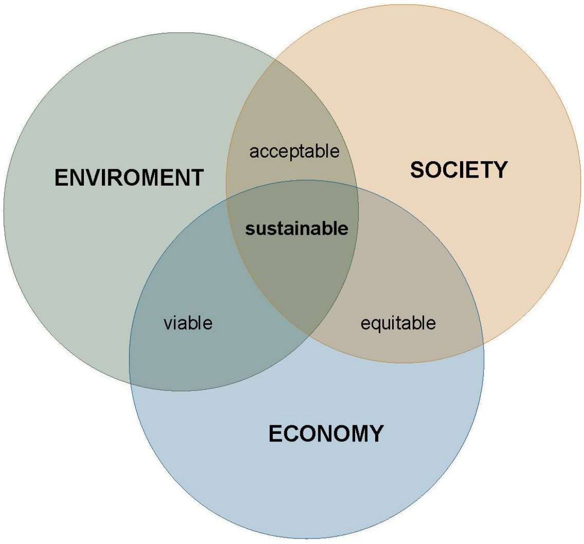

Figure 4: The Three Pillars of Sustainability

a. Environmental Sustainability

Protecting nature is humanity's common goal. Environmental sustainability aspires to protect ecosystems, air quality, and the sustainability of resource, while minimizing factors that apply stress to the environment. In this context, we observe that incentives to use renewable energy power sources are multiplying, concerning both our everyday lives at home and businesses. Living within the means of our natural resources, consuming water, energy, and soil at a sustainable rate, is what environmental sustainability calls for. Furthermore, in the effort to achieve climate change mitigation, net zero carbon footprint is also a prerequisite.[81]

b. Economic Sustainability

In an effort to define economic sustainability we encounter some ambiguity, since disagreements arise upon whether something in economically sound or not. A fundamental requirement for economic sustainability is that each country and business utilize their resources in an efficient way and responsibly, while perceiving the goal to achieve profit in a consistent way. Without profit, no business can sustain its activities in the long term.[82] Economic development goes beyond the strict limits of a business and expands to consequently affect jobs and employability. From a state's perspective, what is

[81] Introduction to Sustainability Guide. (n.d.). Retrieved from Circular Ecology website: https://circularecology.com/introduction-to-sustainability-guide.html

[82] Mason, M. (2014). What is sustainability and why is it important? Retrieved from Environmentalscience.org website: https://www.environmentalscience.org/sustainability

important, is providing incentives for businesses and related organizations to comply with legal requirements -as a minimum- and respect sustainability guidelines beyond this, in the effort to improve the *"standard of living".*

c. Social Sustainability

Social sustainability seeks to continually achieve a good social wellbeing and maintaining it in the long term. This facet of sustainability is the least studied[83] but the most complex. Human health and wellness protection are found in the core of this pillar, as well as is the necessity to protect humanity from pollution and harmful elements. Satisfaction of basic human needs without the compromise of life quality is considered as the bare minimum.

The three-pillar approach is crucial in the effort to achieve sustainability since the main problem we are faced with when assessing policies, and in our case biofuel policies, is that they often seem to only support one pillar, frequently at the cost of the others.[84] Moreover, researches have quickly understood that in the attempt to achieve sustainability, more challenges may come up, so they have started to expand the fundamental pillars; using as a minimum the following factors a)environmental protection, b) economic growth, and c) social equity, they have progressed to include more dimensions such as the institutional,[85] cultural,[86] and technological[87] one.

3.2 Sustainability in the biofuels' context

Having already presented the technical aspects of biofuels and the consequent sustainability challenges and having defined sustainability and sustainable development in the previous subchapter (*See 3.1 Defining Sustainability*), we now have to explain how these intersect.

[83] Svara, J., Watt, T., & Takai, K. (2015). Advancing Social Equity as an Integral Dimension of Sustainability in Local Communities. *Cityscape*, 17(2), 139–166. Retrieved from http://www.jstor.org/stable/26326943
[84] Swiss Learning Exchange. (2020). Episode 6: The 3 Pillars of Sustainability | Sustainable Development | SDG Plus [YouTube Video]. Retrieved from https://www.youtube.com/watch?v=ij SSe66865w&ab_channel=SwissLearningExchange
[85] O'Connor, M. (2006). The "Four Spheres" framework for sustainability. *Ecological Complexity*, 3(4), 285–292. https://doi.org/10.1016/j.ecocom.2007.02.002
[86] Nurse, K. (2006). Culture as the fourth pillar of sustainable development. *Small States: Economic Review and Basic Statistics*, 11, 28–40
[87] Vos, R. O. (2007). Defining sustainability: a conceptual orientation. *Journal of Chemical Technology & Biotechnology*, 82(4), 334–339. https://doi.org/10.1002/jctb.1675

Producing biofuels sustainably can occur while taking into consideration the three pillars of sustainability mentioned above and thus, via practices that avoid environmental, economic and social repercussions. In other words, sustainable biofuels have to be ecologically sound, economically profitable and socially just simultaneously. Having being introduced as a solution to some of humanity's biggest problems and aiming to reduce GHG emissions while providing energy security, biofuels have already been scrutinized as not being "a green alternative to fossil fuels" due to various environmental side-effects (as we have already discussed *in Chapter 2*).

Practically, and since sustainable biomass could have different meanings among governments, societies and individuals, this requires a relative weighting among the socio-economic and environmental impacts. This prioritization differs among different countries and societies but also over time, the reason being their different approaches, needs and objectives.[88] For example, a developing country seeking economic prosperity could "sacrifice" the social and environmental pillar for this purpose.[89]

The following question arises: Can we ensure that the biofuels' production process does not cause harmful consequences? For irreversible impacts to be avoided, it is necessary to identify which practices must be applied starting from the land and resources used to produce feedstocks, along with an assessment of the process until biofuels' consumption. The production and consumption processes must be regulated so as to meet the sustainability requirements set in each case.

Ensuring that sustainability is the guideline leading biofuels' production and consumption is important but we have to figure out the way to achieve it. It has been already highlighted that sustainability is ambiguous and means different things in different contexts. Baring that in mind, it becomes obvious that science cannot provide us with a universal solution for sustainable biofuels; specialists can only research and present the potential consequences of each different option (as established *under Chapter 2* for biofuels).

Biofuels' compliance with sustainability can become a reality, when this is set as the minimum requirement in national legislations, relevant guidelines, certification standards and international policies.[90] For governments, international organizations or even

[88] Dale, V. H., Kline, K. L., Kaffka, S. R., & Langeveld, J. W. A. (2012). A landscape perspective on sustainability of agricultural systems. *Landscape Ecology*, 28(6), 1111–1123. https://doi.org/10.1007/s10980-012-9814-4

[89] This has happened in the case of China, where since 1978 and while targeting economic prosperity, the social and environmental pillars took a hit with land and air pollution, poor animal welfare and a plethora of heath issues being the direct effect of economic growth-based decisions.

[90] Englund, O. (2016*). On sustainability of biomass for energy and the governance thereof*. https://doi.org/10.13140/RG.2.1.2689.4323

societies to be able to define and regulate 'sustainable biofuels', the before-mentioned scientific knowledge will play a pivotal role: after having being informed for the different pathways and resultant aftermaths, they can ultimately make informed choices for their policies/legislations/regulations depending on their preferences and priorities. In this way, biofuels will eventually serve their role as "green energy" without the consequent harmful repercussions with which some of the biofuels' generations are associated currently.

3.3 The sustainable biofuels governance challenge

We have just explained, in the previous *subchapter*, that sustainability notions can significantly vary among countries, societies, over time and due to conflicting interests or political aims. However, biofuels have been introduced in order to solve major global challenges via contributing to climate change alleviation and promoting energy sufficiency and security. Different approaches to their sustainability and thus different requirements from different states, could be barriers in this effort. This is why since their emergence in 1970s and their promotion with different policies, starting in the 1990s,[91] they have swapped from being a purely domestic affair, to an international one.[92]

Even though it has been widely accepted that proper regulation could not only be achieved merely at national level, since we are dealing with an international affair (biofuels are globally produced and consumed, but also traded among different countries), national legislations still *prevail*, as various specialists in the field have repeatedly argued. Moreover, existing global initiatives have been proven to be discordant. Barring these parameters in mind, we cannot disagree that their transnational governance is becoming more and more imperative.[93],[94] Global governance is a concept newly introduced to international relations, linked to globalization and the fact that multiple modern issues (such as sustainable biofuels in our case) expand beyond the national borders and need to be treated in a transboundary way.[95]

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[91] Bailis, R., & Baka, J. (2011). Constructing Sustainable Biofuels: Governance of the Emerging Biofuel Economy. *Annals of the Association of American Geographers*, 101(4), 827–838. https://doi.org/10.1080/00045608.2011.568867

[92] Stattman, S. L. (2019). *Biofuel governance in Brazil and the EU* (PhD Thesis). https://doi.org/10.18174/472916, Retrieved from https://research.wur.nl/en/publications/biofuel-governance-in-brazil-and-the-eu

[93] Bailis, R., & Baka, J. (2011). Constructing Sustainable Biofuels: Governance of the Emerging Biofuel Economy. *Annals of the Association of American Geographers*, 101(4), 827–838. https://doi.org/10.1080/00045608.2011.568867

[94] Bastos Lima, Mairon, & Gupta, J. (2013). The policy context of biofuels: A case of non-governance at the global level? *Global Environmental Politics*, 13, 48–66. https://doi.org/10.1162/GLEP_a_00166

[95] Mukhtarov, F., Pierce, R., & Osseweijer, P. (2014). Global governance of biofuels: A case for public-private governance? *Applied and Bio-Based Economics*, 3. https://doi.org/10.13128/BAE-14767

Besides the complexities that different national regimes cause in biofuels' governance, and the inexistence of international widely-accepted regimes or guidelines, another dimension also perplexes the situation: this of diverse actors being involved in the determination of what sustainability for biofuels calls for. Equally private and public actors introduce principles, criteria and standards to promote sustainable consumption and production (SCP) of biofuels. States are in search of ways to form their own unique policy, while having to balance their purposes with these of private actors and also taking into consideration the impacts of the initiatives and the principles that the latter have already introduced (e.g. private certification standards). Ultimately, this variety of different -and at times conflicting- guidelines do (and eventually will) generate an inevitable confusion, especially to producers and consumers of biofuels,[96] a confusion which, in order to be tackled, will require new regulations, causing even more uncertainty and not fulfilling the purpose of a straightforward framework.

To add on the perplexities described, we should also remember that biofuels are characterized as a "*crosscutting industry*",[97] influencing -and being influenced by- various areas (and thus states' policies) among which climate change mitigation, the food industry, agriculture and land use, energy and transportation etc. This increases the challenge of their sustainable governance due to the complex interactions between biofuels and each of the abovementioned fields, resulting in consequent perplexities in policy-making and governance. Potential weak points in policies or wrong regulations could jeopardize both efficient sustainable governance of biofuels and impact these other areas significantly.

Given all of the above, a common global regulating path seems imperative. But we have mentioned that this seems almost impossible to be achieved: different interests at stake, different regulations formulating differing paths, multiple sectors and actors involved. It is certain that for common ground solutions to be achieved, private and public actors, governments and non-state stakeholders have to come to certain agreements. The cornerstone for successful biofuels global governance is found, according to researchers,[98] in the collaboration between private actors and governments.

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[96] Stattman, S. L. (2019). *Biofuel governance in Brazil and the EU* (PhD Thesis). https://doi.org/10.18174/472916, Retrieved from https://research.wur.nl/en/publications/biofuel-governance-in-brazil-and-the-eu

[97] Bastos Lima, Mairon, & Gupta, J. (2013). The policy context of biofuels: A case of non-governance at the global level? *Global Environmental Politics*, 13, 48–66. https://doi.org/10.1162/GLEP_a_00166

[98] Mukhtarov, F., Pierce, R., & Osseweijer, P. (2014). Global governance of biofuels: A case for public-private governance? *Applied and Bio-Based Economics*, 3. https://doi.org/10.13128/BAE-14767

Chapter 4: Biofuel policies around the globe

In *Chapter 3* we elaborated on the complexities surrounding the global governance of biofuels and we reached the conclusion that event though they are a global affair, which should be regulated at an international level, they are still mostly managed domestically. In the present chapter, after discussing the existing international framework, we will present current national and supranational (with the example of the EU) policies, which will then be assessed on whether they can lead to a sustainable governance of biofuels.

Policy has a central role in the viable and just development of biofuels, since, as we highlighted in earlier chapters, biofuels are an industry at developing stage, with ongoing research surrounding the -currently immature- technology and which, without the governmental support via policies, could not have managed to increase in production and consumption as dramatically.[99]

4.1 On the (in) existence of an international regime for biofuels.

The global environment and economy are in the center of sustainability-oriented concerns about biofuels, and in this sense, we could not avoid to research whether and in what extent, there exists an international framework surrounding biofuels. Furthermore, as far as developing countries are concerned, biofuels production has increased, due to the augmenting demand -*at an international level-* for these alternative fuels, which subsequently has proven to have detrimental repercussions in the local ecosystem and social sustainability, while it could jeopardize the -already at stake- food security (in the terms of future food availability).[100]

In the international context, focusing on global environmental law as a basis in our debate, we have to examine whether a certain *regime* has already been formed and established for (sustainable) biofuels. *International regimes* are defined as a "*set of implicit or explicit principles, norms, rules, and decision-making procedures around which actors' expectations converge*".[101] International regimes are not simply international treaties, they go beyond that, relying on informal norms and rules, on relevant principles of general international law, on norms that have been developed in other treaty regimes

[99] Su, Y., Zhang, P., & Su, Y. (2015). An overview of biofuels policies and industrialization in the major biofuel producing countries. *Renewable and Sustainable Energy Reviews*, 50, 991–1003. https://doi.org/10.1016/j.rser.2015.04.032
[100] Albatayneh, A., Al-Khasawneh, Y., Alawneh, F., Alkhazali, A., & Mohaidat, S. (2019). Biofuel in Developing Countries—Ethical Concerns. *Advanced Studies in Energy Efficiency and Built Environment for Developing Countries*, 149–154. https://doi.org/10.1007/978-3-030-10856-4_13
[101] Krasner, S. D. (1983). *International regimes*. Ithaca: Cornell University Press.

and international bodies, on policies and regulations, on institutions and Court decisions at national, regional and international levels, in order to guide but also enforce a particular standard behavior for the numerous and different actors involved in a particular area of international relations, without, however, legislative enforcement.[102] The effectiveness of an international regime depends on the operations of the governments, international bodies, institutions, and organizations involved.[103] In the area of biofuels, and more broadly bioenergy, such a regime has not been established yet[104] due to the governance complexities analyzed in the previous chapter.

However, other international regimes are of relevance when it comes to sustainable biofuels, since, as we have argued before, biofuels are a "*crosscutting industry*",[105] among which:[106]

The international regime on climate change

When it comes to international climate change law, as a part of international environmental law, the UN climate change regime seems to be at the core, with other general rules and principles of international law playing an equally important role. The relation with biofuels is evident, with climate change mitigation being one of the leading purposes for biofuels' development and global use. In that sense, biofuels should respect the most fundamental obligation set in *Articles 3§3*[107] and *4§1b*[108] of the 1992 *United Nations Framework Convention on Climate Change* (UNFCCC),[109] extended with the *Kyoto*

[102] Gareau, B. J., & Crow, B. (2006). Ken Conca, Governing Water: Contentious Transnational Politics and Global Institution Building. *International Environmental Agreements: Politics, Law and Economics*, 6(3), 317–320. https://doi.org/10.1007/s10784-006-9007-1
[103] Benedict, K. (2001). Global Governance. *International Encyclopedia of the Social & Behavioral Sciences*, 6232–6237. https://doi.org/10.1016/b0-08-043076-7/04499-5
[104] Yue, T. (2016). The International Regulation of the Sustainability of Biofuels. In Different Paths Towards Sustainable Biofuels?: A Comparative Study of the International, EU, and Chinese Regulation of the Sustainability of Biofuels (pp. 29-94). Intersentia. doi:10.1017/9781780687278.002
[105] Bastos Lima, Mairon. (2009). *Biofuel governance and international legal principles: Is it equitable and sustainable?*
[106] Yue, T. (2016). The International Regulation of the Sustainability of Biofuels. In Different Paths Towards Sustainable Biofuels?: A Comparative Study of the International, EU, and Chinese Regulation of the Sustainability of Biofuels (pp. 29-94). Intersentia. doi:10.1017/9781780687278.002
[107] Article 3§3 of the UNFCCC: "The Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects [..]"
[108] Article 4§1b of the UNFCCC: "All parties shall formulate, implement, publish and regularly update national and, where appropriate, regional programmes containing measures to mitigate climate change by addressing anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, and measures to facilitate adequate adaptation to climate change"
[109] United Nations Framework Convention on Climate Change. (1992). Retrieved from https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf

Protocol,[110] (*Article 3)*[111] and then reevaluated with the 2015 *Paris Agreement*[112] (*Articles 2§1b*[113] *and 4§1*[114]): the GHG emission reduction obligation.

Taking into consideration the controversy[115] surrounding biofuels' carbon footprint, with specialists arguing that, the way that these alternative fuels are currently produced and used, leads to elevated rather than reduced greenhouse gases, we can understand that, at least in compliance with the international regime on climate change, countries should focus on promoting biofuels that are produced in such circumstances[116] that can achieve carbon neutrality, in order for them to respect the "GHG emission reduction obligation". In this sense, we now realize that, even though there is not a global biofuel-related regime, other regimes do provide some relating general principles and guidelines.

The biodiversity regime

When it comes to biodiversity, existing international regimes have mainly been surrounded around the *Convention on Biological Diversity* (CBD)[117] (*Article 6 (a) and (b) mainly)*[118] and the *Ramsar Convention.*[119] The biofuels' potential negative impacts leading to biodiversity loss have been briefly approached under *Chapter 2* and will be more in-depth discussed in next chapters. For the purpose of our current discussion, biodiversity conservation should be viewed as a guideline which must be taken into consideration when biofuel policies are created and implemented. In this direction, the Secretariat

[110] Kyoto Protocol. (1997). Retrieved from Unfccc.int website: https://unfccc.int/kyoto-protocol-html-version
[111] Article 3 of the Kyoto Protocol: "The Parties shall, individually or jointly, ensure that their aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases [..]"
[112] United Nations Climate Change. (2015). The Paris Agreement | UNFCCC. Retrieved from Unfccc.int website: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[113] Article 2§1b of the Paris Agreement: "Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production"
[114] Article 4§1 of the Paris Agreement: "to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty"
[115] Steer, A. (2015). Biofuels are not a green alternative to fossil fuels. Retrieved from the Guardian website: https://www.theguardian.com/environment/2015/jan/29/biofuels-are-not-the-green-alternative-to-fossil-fuels-they-are-sold-as
[116] DeCicco, J. M. (2013). Biofuel's carbon balance: doubts, certainties and implications. *Climatic Change*, 121(4), 801–814. https://doi.org/10.1007/s10584-013-0927-9
[117] The Convention on Biological Diversity. (1993). Retrieved from Cbd.int website: https://www.cbd.int/convention/
[118] Article 6 of the CBD: "Each Contracting Party shall, in accordance with its particular conditions and capabilities: (a) Develop national strategies, plans or programmes for the conservation and sustainable use of biological diversity or adapt for this purpose existing strategies, plans or programmes which shall reflect, inter alia, the measures set out in this Convention relevant to the Contracting Party concerned; and (b) Integrate, as far as possible and as appropriate, the conservation and sustainable use of biological diversity into relevant sectoral or cross-sectoral plans, programmes and policies".
[119] The Ramsar Convention. (1971). Retrieved from https://www.ramsar.org/sites/default/files/documents/library/current_convention_text_e.pdf

of the Convention on Biological Diversity has published in 2012 a report[120] in which they present their views regarding the interrelation of biofuels with biodiversity.

The regime surrounding socio-economic rights

As with the previous regimes, the International Covenant on Economic, Social, and Cultural Rights (ICESCR)[121] (mainly *Article 11§1)*[122] and the related regime is of interest in biofuel policies, which, when formed and implemented via regulations, should not jeopardize the food, water and land rights, which, as already mentioned, can be affected by large-scale and unstainable biofuel production.

The World Trade Organization (WTO) regime

An increasing demand for biofuels, the promising alternative to fossil fuels, has been observed internationally, with a subsequent rise in biofuels' global trade. When it comes to the trade order of the WTO being applied to biofuels, multiple problems emerge; specific rules have not been created and enforced for biofuels yet, and hence general principles and guidelines have to guide the international biofuel market. But which general WTO principles will apply?

In such debates, biofuels classification along with other parameters affect the final specific scheme to be implemented, which differs accordingly, and creates a legal uncertainty. Of course, complexities can also arise, due to these international trade rules conflicting with norms and principles inherent to the three aforementioned regimes. Besides that, the need for a stable regime for biofuels' international trade seems also necessary in the case of developing countries that, on the one hand are major exporters of biofuels, and on the other have to abide by the importer country's sustainability requirements.[123]

We can understand that, even though a universal biofuel trade regime has not been established to the present day, different WTO principles are applied, varying according to the category of biofuels and the specific parameters, a situation which primarily causes legal uncertainty and calls for unambiguous regulations and a reality which

[120] Webb, A. and D. Coates (2012). Biofuels and Biodiversity. Secretariat of the Convention on Biological Diversity. Montreal, Technical Series No. 65, 69 pages
[121] OHCHR | International Covenant on Economic, Social and Cultural Rights. (1976). Retrieved from Ohchr.org website: https://www.ohchr.org/en/professionalinterest/pages/cescr.aspx
[122] Article 11§1 of the ICESCR: "The States Parties to the present Covenant recognize the right of everyone to an adequate standard of living for himself and his family, including adequate food, clothing and housing, and to the continuous improvement of living conditions".
[123] Weiß, W. (2010). Biofuels and WTO Law. *European Yearbook of International Economic Law 2011*, 169–203. https://doi.org/10.1007/978-3-642-14432-5_8

nonetheless affects the current biofuels' global governance and regional and national policy formation.

The inexistence of a specifically dedicated to biofuels international regime does not mean that there are not international guidelines and norms, as well as regimes which have been formed for different sectors, yet, which do affect the formations of domestic policies and thus guide and -at times- restrict domestic regulations.

4.1.1 International Environmental Law Principles relevant to biofuels' sustainable development

Humanity is faced with more and more significant challenges at a global level; transboundary pollution is one of them, being mainly caused locally but still not being effectively tackled at a domestic level. In that sense, the international legal system, in order to provide a satisfying response to new challenges, must influence national policies of states and use national institutions to achieve global goals.

Given the above, it is certain that fundamental international environmental law principles should guide national policies promoting biofuels so as to ensure their sustainability, so as to certify that they exist as a solution to the climate change problem and not as an additional aggravating factor. Besides the newly-introduced to international environmental law, *principle of sustainable development*, which is at the core of our current discussion, and which was analyzed in the previous chapter, having being defined by the Brundtland Commission, as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*"[124] and moreover having being further clarified with Rio Convention's following principles:[125]

Principle 3

The right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations.

Principle 4

In order to achieve sustainable development, environmental protection shall constitute an integral part of the development process and cannot be considered in isolation from it.

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[124] Report of the World Commission on Environment and Development : (1987). *United Nations Digital Library System*. Retrieved from https://digitallibrary.un.org/record/139811?ln=en

[125] Rio Declaration on Environment and Development. (1992). Retrieved from Cbd.int website: https://www.cbd.int/doc/ref/rio-declaration.shtml

two more principles,[126] inextricably linked with this fundamental principle, must be considered and respected:

i. The precautionary principle, having been introduced with the Rio Convention[127]

Principle 15

In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

and being interestingly relevant in the biofuels context regarding the new technology surrounding them, which at times causes "scientific uncertainty".

ii. The principle of intra- and inter- generational equity

Intragenerational equity - which is about meeting the needs of current generations must be aligned with meeting the basic needs of *all future global citizens.* The principle, considered as one of the foundations of sustainable development, necessitates for *fairness* among generations regarding environmental and natural resources preservation.[128]

4.2 National Policies

Biofuels are currently almost completely managed at domestic level with national policies playing a key role in their consumption and production, being the ones mainly affecting the international circulation of biofuels since, as mentioned above, an international universal regime does not exist and a relevant international approach is currently rather limited. Liquid biofuels would not have developed in such a rapid rhythm, if it were not for governmental intervention through policies.[129]

In the subchapters to follow, we will analyze current national policies in the U.S. and Brazil, given that Brazil is the world's second largest producer and has led (along with

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126 Βρετού, Β. (2019). Οι βασικές αρχές του διεθνούς περιβαλλοντικού δικαίου και οι μελλοντικές γενιές. Retrieved from Νόμος και Φύση website: https://nomosphysis.org.gr/19578/oi-vasikes-arxes-toy-diethnoys-perivallontikoy-dikaioy-kai-oi-mellontikes-genies/#_ftn16

127 Rio Declaration on Environment and Development. (1992). Retrieved from Cbd.int website: https://www.cbd.int/doc/ref/rio-declaration.shtml

128 Brown Weiss, E. (2013). Intergenerational Equity. In Max Planck Encyclopedia of Public International Law [MPEPIL]. Retrieved from https://opil.ouplaw.com/view/10.1093/law:epil/9780199231690/law-9780199231690-e1421#:~:text=1%20The%20principle%20of%20intergenerational,other%20generations%2C%20past%20and%20future.&text=The%20principle%20is%20the%20foundation%20of%20sustainable%20development.

129 Stattman, S. L. (2019). *Biofuel governance in Brazil and the EU* (PhD Thesis). https://doi.org/10.18174/472916, Retrieved from https://research.wur.nl/en/publications/biofuel-governance-in-brazil-and-the-eu

the U.S) the production of ethanol fuel, together producing 84% of the world's ethanol[130] as of 2019 (See *Figure 5*: Global Ethanol Production). China's policies are also worth mentioning, since it has actively entered the biofuels field, especially with ethanol production as shown in the *figure* below, however its policies need to be further improved, as we will discuss in the relevant subchapter.

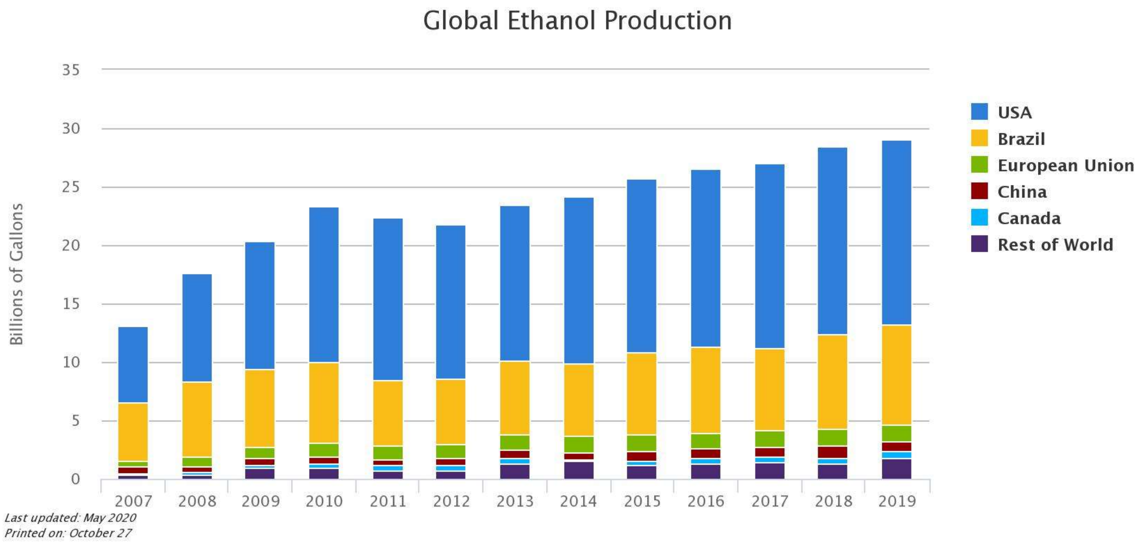

Figure 5: Global Ethanol Production[131]

4.2.1 The U.S

Since the early 2000s, the United States, currently the largest producer of biofuels in the globe (See *Figure 6)*, has tried to achieve large-scale consumption and production of biofuels, through various policies (that include credit facilities, mandates, tax credits, and import tariffs).

[130] Alternative Fuels Data Center: Maps and Data - Global Ethanol Production. (2019). Retrieved from Energy.gov website: https://afdc.energy.gov/data/10331
[131] Alternative Fuels Data Center: Maps and Data - Global Ethanol Production. (2019). Retrieved from Energy.gov website: https://afdc.energy.gov/data/10331

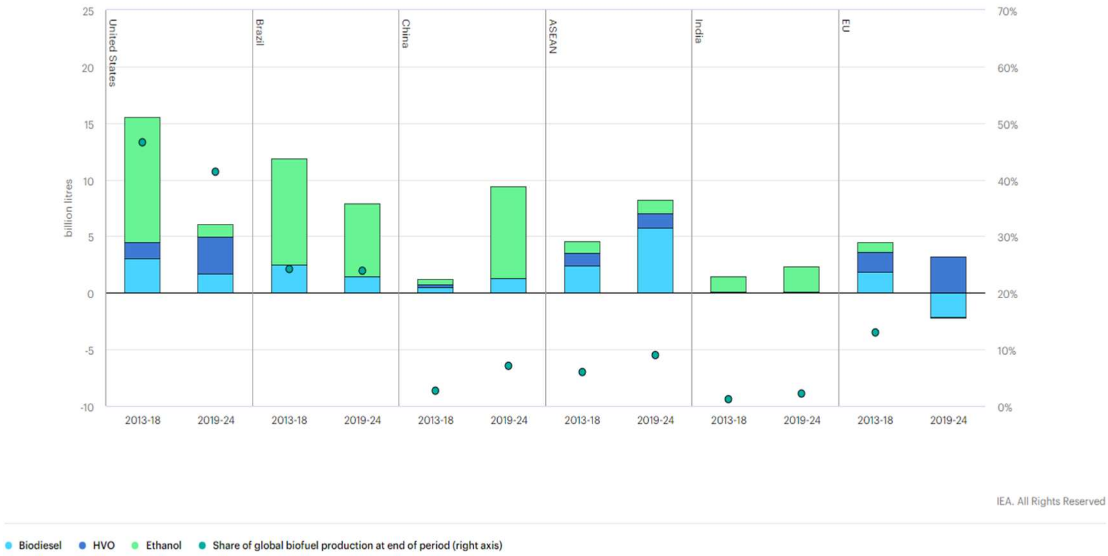

Figure 6: Biofuels Production around the globe[132]

The first notable step towards this direction was made in 2005, with the US Congress passing the *Energy Policy Act.*[133] Under this *Act*, the active incorporation of -cellulosic-biofuels (mainly ethanol and biodiesel) was significantly encouraged, principally with highlighting the importance of providing production incentives. In that sense, in a provision of the *Act,* the *Renewable Fuels Standard* (RFS) was established, mandating a minimum amount of renewable fuel to be contained in transportation fuel (4 billion gallons in 2006, which was augmented to 7.5 billion gallons in 2012).[134] Additionally, regarding the entities that either develop or use new technologies that encompass procedures which decrease incidental GHG production,[135] noticeable credit facilities were introduced. Finally, a tax credit and import tariff were introduced for imported ethanol, rendering it more expensive, aiming to protect the domestic corn ethanol, which are now repealed due to unintended consequences that have occurred during the development of this field.[136]

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[132] IEA. (n.d.). Biofuels production growth by country/region – Charts – Data & Statistics. Retrieved from IEA website: https://www.iea.org/data-and-statistics/charts/biofuels-production-growth-by-country-region. All rights reserved.
[133] *Energy Policy Act of 2005*. (2005). Retrieved from https://www.congress.gov/109/plaws/publ58/ PLAW-109publ58.pdf
[134] Schnepf, R., & Yacobucci, B. (2013). CRS Report for Congress Prepared for Members and Committees of Congress Renewable Fuel Standard (RFS): Overview and Issues Randy Schnepf Specialist in Agricultural Policy. Retrieved from https://fas.org/sgp/crs/misc/R40155.pdf
[135] US EPA. (2018). Summary of the Energy Policy Act. Retrieved from US EPA website: https://www.epa.gov/laws-regulations/summary-energy-policy-act
[136] Hochman, G., Traux, M., & Zilberman, D. (2017). US Biofuel Policies and Markets. *Handbook of Bioenergy Economics and Policy: Volume II*, 15–38. https://doi.org/10.1007/978-1-4939-6906-7_2

The *Energy Independence and Security Act of 2007* (EISA 2007),[137] which followed, expanded and extended the *Renewable Fuel Standard* (RFS), via increasing the mandated levels to a total of 36 billion gallons in 2022.[138] In 2010, the RFS was updated again (referred to as *RFS2*), and provided that a reduction of at least 20% in life cycle GHG emissions must be proved for conventional (first-generation) biofuels and that it is through *advanced biofuels* that a decrease in GHG emissions can be achieved, in which a reduction of at least 50% must be demonstrated.[139] The GHG emission reduction approach, indicated that an additional objective for biofuels development in the US has been introduced: the minimization of the effects that fuel used for transportation bares on global climate change.[140] However, it seems like the guiding principle in US biofuel policies in no other than a reduction in the country's oil dependency.[141]

At this point we should mention that the RFS has caused much controversy among experts in the field, regarding its implications on fuel prices, with some arguing that government policy setting the demand for fuel, via imposing a minimum amount of renewable fuels to be blended, could lead to adverse economic effects and could jeopardize economic viability, while others have supported that the introduction of biofuels leads to a decrease in oil prices and subsequently to lower fuel prices.[142]

Besides the RFS, biofuels development has been encouraged with production incentives. In 1978, with the *Energy Tax Act of 1978,*[143] the United States became the first country to provide a tax exemption to fuel blenders[144] with establishing a federal-level subsidy of the amount of US $0.40 per ethanol gallon. This federal tax credit increased in 1982[145] to US$0.50 per gallon of ethanol and to US$0.60 in 1984,[146] only to start

[137] Energy Independence and Security Act of 2007. (2007). Retrieved from https://afdc.energy.gov/laws/eisa.html
[138] However, in 2019, EPA (the Environmental Protection Agency) decided to increase the advanced biofuel mandate for 2020 (+0.6 bln L).
[139] Sorda, G., Banse, M., & Kemfert, C. (2010). An overview of biofuel policies across the world. *Energy Policy*, 38(11), 6977–6988. https://doi.org/10.1016/j.enpol.2010.06.066
[140] Office, U. S. G. A. (2016*). Renewable Fuel Standard: Program Unlikely to Meet Its Targets for Reducing Greenhouse Gas Emissions.* (GAO-17-94). Retrieved from https://www.gao.gov/products/GAO-17-94
[141]Sorda, G., Banse, M., & Kemfert, C. (2010). An overview of biofuel policies across the world. *Energy Policy*, 38(11), 6977–6988. https://doi.org/10.1016/j.enpol.2010.06.066
[142] Hochman, G., Traux, M., & Zilberman, D. (2017). US Biofuel Policies and Markets. *Handbook of Bioenergy Economics and Policy: Volume II*, 15–38. https://doi.org/10.1007/978-1-4939-6906-7_2
[143] H.R.5263 - 95th Congress (1977-1978): Energy Tax Act. (1978). Retrieved from www.congress.gov website: https://www.congress.gov/bill/95th-congress/house-bill/5263
[144] Hochman, G., Traux, M., & Zilberman, D. (2017). US Biofuel Policies and Markets. *Handbook of Bioenergy Economics and Policy: Volume II*, 15–38. https://doi.org/10.1007/978-1-4939-6906-7_2
[145] Surface Transportation Assistance Act of 1982 (1983 - H.R. 6211). (1982). Retrieved from GovTrack.us website: https://www.govtrack.us/congress/bills/97/hr6211
[146] With the Tax Reform Act of 1984, Tyner, W. E. (2008). The US Ethanol and Biofuels Boom: Its Origins, Current Status, and Future Prospects. *BioScience*, 58(7), 646–653. https://doi.org/10.1641/b580718

steadily decreasing after 1990,[147] reaching to US $0.45 per gallon in 2009[148] and finally being eliminated at the end of December 2011.[149]

On the other hand, the biodiesel tax credit (BTC), already established under the American Jobs Creation Act of 2004,[150] had reached the amount of US $1 per gallon of biodiesel incorporated with normal diesel by 2011, with Congress having a history of extending after 2016 (when it expired) retroactively for the previous year.[151] In fact, in 2013 and 2016, years during which biodiesel production took place *while* the BTC was in force, national-level production as well as imports were at higher levels compared to the years when BTC was only applied retroactively.[152]

In addition to the tax credits mentioned *above,* there is also the *Cellulosic producer tax credit* as well as some *Ethanol blender pump subsidies* at federal level,[153] but also every U.S. state can apply additional tax credits/exemptions locally. Moreover, we should underline that, as it has already been implied, the tax credits were also applicable to biofuels importers, which meant that this could put at risk the domestic biofuel industry. In that sense, and aiming to protect local producers -creating a barrier in biofuel imports (mostly form Brazil)- an import duty of $0.54 per gallon, along with an out-of-quota ad valorem import tariff of 2.5 % for ethanol, was in effect until January 2012.[154]

It seems that energy and environmental protection are in the center of U.S. biofuels policy's interests, but it has been found that this policy has other, severe effects, on food prices and the food system in general, since maize (the main feedstock used for biofuels in the U.S.) as well as other feedstocks used as sources for biofuels, are also intended for the production for feed and food,[155] subsequently causing a conflict between fuels and food.

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[147] H.R.5835 - 101st Congress (1989-1990): Omnibus Budget Reconciliation Act of 1990. (1990). Retrieved from www.congress.gov website: https://www.congress.gov/bill/101st-congress/house-bill/5835/text

[148] Jales, M. de Q. M., & Costa, C. C. da. (2014). Measurement of ethanol subsidies and associated economic distortions: an analysis of Brazilian and U.S. policies. *Economia Aplicada*, 18(3), 455–481. https://doi.org/10.1590/1413-8050/ea375

[149] Rajcaniova, M., Ciaian, P., & Drabik, D. (2014). International Policies on Bioenergy and Biofuels. *Handbook of Plant Breeding*, 381–406. https://doi.org/10.1007/978-1-4939-1447-0_18

[150] United States. (2004). American Jobs Creation Act of 2004. Retrieved from https://www.congress.gov/108/plaws/publ357/PLAW-108publ357.pdf

[151] Federal Subsidies for Biofuels and Biomass Energy. (2017). Retrieved from https://www.taxpayer.net/energy-natural-resources/federal-subsidies-biofuels-biomass-energy/

[152] U.S. biomass-based diesel tax credit renewed through 2022 in government spending bill - Today in Energy - U.S. Energy Information Administration (EIA). (2020). Retrieved from www.eia.gov website: https://www.eia.gov/todayinenergy/detail.php?id=42616

[153] Federal Subsidies for Biofuels and Biomass Energy. (2017). Retrieved from https://www.taxpayer.net/energy-natural-resources/federal-subsidies-biofuels-biomass-energy/

[154] Rajcaniova, M., Ciaian, P., & Drabik, D. (2014). International Policies on Bioenergy and Biofuels. *Handbook of Plant Breeding*, 381–406. https://doi.org/10.1007/978-1-4939-1447-0_18

[155] Nesheim, M. C., Oria, M., Yih, P. T., Committee on a Framework for Assessing the Health, E., Board, F. and N., Resources, B. on A. and N., … Council, N. R. (2015). U.S. BIOFUELS POLICY. In www.ncbi.nlm.nih.gov (ANNEX 2). Retrieved from https://www.ncbi.nlm.nih.gov/books/ NBK305179/

4.2.2 Brazil

Brazil, the global pioneer when it comes to biofuels production,[156] being the first country in the world to have introduced the obligation for ethanol mixed in conventional oil,[157] is the only country with a long history of biofuel-related policies at national level. With a focus on ethanol produced from sugarcane – a crop which thrives in Brazil, and for which Brazil is the largest producer in the world[158]-, an obligatory blending of ethanol at 5% was introduced in 1931, firstly as a solution to the concurrent excess of sugar stock and the economic recession of that time.[159] It was not until the 1970s that remarkable progress in this sector started to be noticed, mostly with the establishment of the *National Fuel Alcohol Program (Proálcool)* in 1975, an ethanol program that originated as a reaction to the oil price hike of the time[160] and which aimed to cease dependency on fossil fuels and achieve energy sovereignty.

Starting from this moment, the bioethanol sector in Brazil has further grown and improved, both from an institutional perspective but also with regards to the technology used. A significant milestone has been the inception of flexible fuel vehicles (FFVs) in 2003,[161] presently vastly sold and used in Brazil, which allowed the Brazilian government to guide ethanol consumption via an obligatory blending mandate of ethanol with gasoline.[162] This compulsory blending mandate is currently set at 27% in all commercial gasoline – E27.[163] Moreover, various economic aids and a favorable tax treatment[164] exist regarding ethanol at federal but also at provincial level, while a 20% ad valorem import

[156] In 1919 in the State of Pernambuco (north-eastern in Brazil) the first ethanol policy was introduced, establishing ethanol as an official fuel within this state., Saravanan, A. P., Pugazhendhi, A., & Mathimani, T. (2020). A comprehensive assessment of biofuel policies in the BRICS nations: Implementation, blending target and gaps. *Fuel*, 272, 117635. https://doi.org/https://doi.org/10. 1016/j.fuel.2020.117635
[157] World Energy Council. (2010). *Biofuels: Policies, Standards and Technologies*. Retrieved from https://www.globalccsinstitute.com/archive/hub/publications/155688/biofuels-policies-standards-technologies.pdf
[158] In Brazil, a Sugarcane Rush Poses a New Threat to the Amazon Rainforest. (2020). Retrieved from https://www.sierraclub.org/sierra/brazil-sugarcane-rush-poses-new-threat-amazon-rainforest#:~:text=Brazil%20is%20the%20world
[159] Morone, P., Strzałkowski, A., & Tani, A. (2020). Biofuel transitions: An overview of regulations and standards for a more sustainable framework. *Biofuels for a More Sustainable Future*, 21–46. https://doi.org/10.1016/b978-0-12-815581-3.00002-6
[160] Moschini, G., Cui, J., & Lapan, H. (2012). Economics of Biofuels: An Overview of Policies, Impacts and Prospects. *Bio-Based and Applied Economics*, 1(3), 269-296. https://doi.org/10.13128/BAE-11143
[161] Sorda, G., Banse, M., & Kemfert, C. (2010). An overview of biofuel policies across the world. *Energy Policy*, 38(11), 6977–6988. https://doi.org/10.1016/j.enpol.2010.06.066
[162] Gasparatos, A., Borzoni, M., & Abramovay, R. (2012). The Brazilian bioethanol and biodiesel programs: Drivers, policies, and impacts. *Socioeconomic and Environmental Impacts of Biofuels*, 111–143. https://doi.org/10.1017/cbo9780511920899.010
[163] Brazil: Fuels: Biofuels | Transport Policy. (n.d.). Retrieved from https://www.transportpolicy.net/standard/brazil-fuels-biofuels/#:~:text=Brazil
[164] Biofuels | OECD-FAO Agricultural Outlook 2020-2029 | OECD iLibrary. (n.d.). Retrieved from www.oecd-ilibrary.org website: https://www.oecd-ilibrary.org/sites/3aeb7be3-en/index.html?itemId=/content/component/3aeb7be3-en#section-d1e21123

tariff for countries outside the MERCOSUR[165] has also been at force, mainly affecting the U.S. since ethanol imports originate almost entirely from the U.S;[166] this import duty is currently out of force, with Brazil having introduced a tariff-free quota for ethanol imports this year.[167]

When it comes to biodiesel, Brazil has a shorter history of introducing relevant policies and support programs, starting in 2004/2005 with the *National Program on Biodiesel Production and Usage (PNPB)*, even though biodiesel research had already begun since the 1970s.[168] For biodiesel, mainly originating from soybeans, the mandate in the beginning called for an obligatory blend of biodiesel with conventional diesel at 5%, and a biodiesel import tariff of 14%.[169] This blending level of biodiesel has reached 7% as of November 2014,[170] while other development incentives, including tax exemptions are available.

According to (*Gasparatos, Borzoni, Abramovay, 2012*),[171] the PNPB has three main objectives: the establishment of a competitive (in terms of price and quality) biodiesel production system; the promotion of national energy security via feedstock diversification;[172] the reinforcement of family farming and thus the upgrade of small farmers in the biodiesel field. Besides energy security and agriculture development, PNPB was also driven by social purposes;[173] within this framework, a certification awarded by the Ministry of Agriculture, the Social Fuel Seal (SFS) was also introduced, but controversy arose on whether it actually succeeded in its purpose of social inclusion and several concerns emerged regarding the sustainability related to the role of small farmers.[174]

[165] The South American economic, political and trade bloc established by the Treaty of Asunción in 1991 and Protocol of Ouro Preto in 1994, among Argentina, Brazil, Paraguay and Uruguay

[166] USDA Foreign Agricultural Service. (2019). *Brazil Biofuels Annual Report*. Retrieved from https://apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=Biofuels%20Annual_Sao%20Paulo%20ATO_Brazil_8-9-2019.pdf

[167] Brazil extends tariff-free quota for ethanol. (2020). Retrieved from www.argusmedia.com website: https://www.argusmedia.com/en/news/2140845-brazil-extends-tarifffree-quota-for-ethanol

[168] Gasparatos, A., Borzoni, M., & Abramovay, R. (2012). The Brazilian bioethanol and biodiesel programs: Drivers, policies, and impacts. *Socioeconomic and Environmental Impacts of Biofuels*, 111–143. https://doi.org/10.1017/cbo9780511920899.010

[169] Moschini, G., Cui, J., & Lapan, H. (2012). Economics of Biofuels: An Overview of Policies, Impacts and Prospects. *Bio-Based and Applied Economics*, 1(3), 269-296. https://doi.org/10.13128/BAE-11143

[170] Morone, P., Strzałkowski, A., & Tani, A. (2020). Biofuel transitions: An overview of regulations and standards for a more sustainable framework. *Biofuels for a More Sustainable Future*, 21–46. https://doi.org/10.1016/b978-0-12-815581-3.00002-6

[171] Gasparatos, A., Borzoni, M., & Abramovay, R. (2012). The Brazilian bioethanol and biodiesel programs: Drivers, policies, and impacts. *Socioeconomic and Environmental Impacts of Biofuels*, 111–143. https://doi.org/10.1017/cbo9780511920899.010

[172] The selection of the optimal combination of raw material used to produce biofuels- mainly of interest in biodiesel.

[173]Morone, P., Strzałkowski, A., & Tani, A. (2020). Biofuel transitions: An overview of regulations and standards for a more sustainable framework. *Biofuels for a More Sustainable Future*, 21–46. https://doi.org/10.1016/b978-0-12-815581-3.00002-6

[174] Marcossi, G. P. C., & Moreno-Pérez, O. M. (2017). A closer look at the Brazilian Social Fuel Seal: uptake, operation and dysfunctions. *Biofuels*, 9(4), 429–439. https://doi.org/10.1080/ 17597269.2016.1274163

While it seems like biofuel policies in Brazil are also interrelated with social policies, like we mentioned above, or take into consideration environmental protection, as it happened with *National Biofuels Policy (RenovaBio)* -signed into law in 2017 and having as a main objective the reduction of GHG emissions[175]-, we cannot omit to mention that the implementation of sustainability in biofuel governance in Brazil has caused numerous debates. On the one hand food, feed and fuels have various interdependencies, and biofuels' expansion could have adverse effects on the food system and consequently jeopardize a truly sustainable biofuel development; on the other hand, deforestation in the Amazon has caused an additional controversy with international organizations questioning the environmental safety aspect of the country's policies.[176]

In the end, it is important to highlight that, when it comes to bioethanol policies, a plethora of countries have tried to imitate Brazil's approach, which has been perceived as a pioneering and successful,[177] with the U.S. Environmental Protection Agency (EPA) *nominating ethanol produced from Brazilian sugarcane as an advanced biofuel* in 2010.[178]

4.2.3 China

Having the largest population in the world, China's energy consumption needs are the most elevated globally,[179] while it also produces the highest levels of CO2 emissions. It is easy to understand that, in this context, the two most important reasons for biofuel development in the country are the achievement of energy security via the reduction of the dependence on oil imports, and the depletion of GHG emissions.[180] However, national biofuel policies have not really been developed until 2001, even though a first effort to explore this field had already been made in 1986 with the *National High*

[175] National Biofuels Policy (Brazil)– Policies. (n.d.). Retrieved from IEA website: https://www.iea.org/policies/2475-national-biofuels-policy

[176] Pathak, L., & Shah, K. (2019). Renewable energy resources, policies and gaps in BRICS countries and the global impact. *Frontiers in Energy*, 13(3), 506–521. https://doi.org/10.1007/s11708-018-0601-z

[177] Moschini, G., Cui, J., & Lapan, H. (2012). Economics of Biofuels: An Overview of Policies, Impacts and Prospects. *Bio-Based and Applied Economics*, 1(3), 269-296. https://doi.org/10.13128/BAE-11143

[178] EPA reaffirms sugarcane biofuel is advanced Renewable fuel with 61% less emissions than gasoline - Unica. (2010). Retrieved from english.unica.com.br website: http://english.unica.com.br/news/38990375920334398749/epa-reaffirms-sugarcane-biofuel-is-advanced-renewable-fuel-with-61-por-cento-less-emissions-than-gasoline/

[179] Leading countries for primary energy consumption 2019. (n.d.). Retrieved from Statista website: https://www.statista.com/statistics/263455/primary-energy-consumption-of-selected-countries/

[180] Su, Y., Zhang, P., & Su, Y. (2015). An overview of biofuels policies and industrialization in the major biofuel producing countries. *Renewable and Sustainable Energy Reviews*, 50, 991–1003. https://doi.org/10.1016/j.rser.2015.04.032

Technology Research and Development Initiative (Plan863), under which subsidies and other motives were provided for research on biofuels.[181]

In 2001, *The Special Development Plan for Denatured Fuel Ethanol and Bioethanol Gasoline for Automobiles in the 10th Five-Year Period (2001-2005) (the Plan)* was put into force, and standards for bioethanol gasoline and denatured fuel ethanol were adopted.[182] The use of E10 (the mandatory blending of ethanol to gasoline at 10%) has been established since 2002[183] mainly aiming to take advantage of the excessive maize that had accumulated at that time because of a corn overproduction promoted by agricultural policies.[184] This was repeated in 2017, when, due to excessive corn stockpiles, China passed a new nationwide E10 mandate, which in the beginning only concerned 11 provinces and which eventually expanded to 26 by 2020.[185]

Biofuel policies[186] in the country focus on ethanol while biodiesel has not been promoted by policies with the same intensity.[187] Biodiesel production may have initiated in 2001, and it is worth mentioning that waste oil was used as feedstock, however official policies have not been developed in this direction.[188] Moreover, financial incentives directly concerning biodiesel have not been established, nor do national biodiesel standards exist,[189] except for a voluntary biodiesel standard introduced in 2007.[190]

However, the Ministry of Finance introduced, in 2012, subsidies for the promotion of renewable power generation in general,[191] applicable in both ethanol and biodiesel,

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181 Saravanan, A. P., Pugazhendhi, A., & Mathimani, T. (2020). A comprehensive assessment of biofuel policies in the BRICS nations: Implementation, blending target and gaps. *Fuel*, 272, 117635. https://doi.org/https://doi.org/10. 1016/j.fuel.2020.117635
182 Tao, J., Yu, S., & Wu, T. (2011). Review of China's bioethanol development and a case study of fuel supply, demand and distribution of bioethanol expansion by national application of E10. *Biomass and Bioenergy*, 35(9), 3810–3829. https://doi.org/10.1016/j.biombioe.2011.06.039
183 Biofuels | OECD-FAO Agricultural Outlook 2020-2029 | OECD iLibrary. (n.d.). Retrieved from www.oecd-ilibrary.org website: https://www.oecd-ilibrary.org/sites/3aeb7be3-en/index.html?itemId=/content/component/3aeb7be3-en#section-d1e21123
184 Tao, J., Yu, S., & Wu, T. (2011). Review of China's bioethanol development and a case study of fuel supply, demand and distribution of bioethanol expansion by national application of E10. *Biomass and Bioenergy*, 35(9), 3810–3829. https://doi.org/10.1016/j.biombioe.2011.06.039
185 Biofuels | OECD-FAO Agricultural Outlook 2020-2029 | OECD iLibrary. (n.d.). Retrieved from www.oecd-ilibrary.org website: https://www.oecd-ilibrary.org/sites/3aeb7be3-en/index.html?itemId=/content/component/3aeb7be3-en#section-d1e21123
186 Of course, besides biofuel policies, biofuels' importance has also been emphasized in the 2006 *Renewable Energy Law* (amended in 2009).
187 Sorda, G., Banse, M., & Kemfert, C. (2010). An overview of biofuel policies across the world. *Energy Policy*, 38(11), 6977–6988. https://doi.org/10.1016/j.enpol.2010.06.066
188 Saravanan, A. P., Pugazhendhi, A., & Mathimani, T. (2020). A comprehensive assessment of biofuel policies in the BRICS nations: Implementation, blending target and gaps. *Fuel*, 272, 117635. https://doi.org/https://doi.org/10. 1016/j.fuel.2020.117635
189 Sorda, G., Banse, M., & Kemfert, C. (2010). An overview of biofuel policies across the world. *Energy Policy*, 38(11), 6977–6988. https://doi.org/10.1016/j.enpol.2010.06.066
190 BIOFUELS -AT WHAT COST ? Government support for ethanol and biodiesel in China. (2008). Retrieved from https://www.iisd.org/gsi/sites/default/files/china_biofuels_subsidies.pdf
191 Saravanan, A. P., Pugazhendhi, A., & Mathimani, T. (2020). A comprehensive assessment of biofuel policies in the BRICS nations: Implementation, blending target and gaps. *Fuel*, 272, 117635. https://doi.org/https://doi.org/10. 1016/j.fuel.2020.117635

while favorable vehicle and fuel taxation, along with economic incentives have also been established for hybrid electric vehicles.[192] Regarding the government funding in the field, we also must emphasize on the *976 Program* under which energy production form microalgae, lignocellulosic material (including forestry-originating biomass) were promoted, and on the *863 Program* which promoted sweet potato as a feedstock for ethanol in the south part of the country, via financial incentives.[193]

With regards to China, there is a consensus, that while the country has been experiencing an outstanding economic growth with a phenomenal advancement in most sectors, this progress has happened at the expense of the environment; this is why policy-makers in the biofuels field should take more intensive measures in the protection of the environment. Afterall, even though research for third and fourth generation biofuels is funded in China, as we already mentioned, the country is still producing and using mostly first generation biofuels (with all the impacts that this could carry, as we mentioned in-*Chapter 2*). Even so, some promising changes towards more sustainable production of biofuels have been made, with the subsidy policies and tax favorable regulations being suspended for crop-originating ethanol and only being maintained for the other types of bioethanol.[194]

Finally, it is more than probable that the country will have to reconsider biofuel policies soon, since it is estimated that fossil fuel currently meets only 70% of the increased national energy demands[195] and since biofuels production can potentially have some severe impacts on the food system.[196]

4.3 Supranational policies - The EU

After having presented three of the most important national biofuel policies, these of the U.S., Brazil, and China, we will now move on to the European biofuels' framework and we will try to present the most important of its components. We have always to take into

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[192] Pathak, L., & Shah, K. (2019). Renewable energy resources, policies and gaps in BRICS countries and the global impact. *Frontiers in Energy*, 13(3), 506–521. https://doi.org/10.1007/s11708-018-0601-z

[193] Saravanan, A. P., Pugazhendhi, A., & Mathimani, T. (2020). A comprehensive assessment of biofuel policies in the BRICS nations: Implementation, blending target and gaps. *Fuel*, 272, 117635. https://doi.org/https://doi.org/10. 1016/j.fuel.2020.117635

[194] Morone, P., Strzałkowski, A., & Tani, A. (2020). Biofuel transitions: An overview of regulations and standards for a more sustainable framework. *Biofuels for a More Sustainable Future*, 21–46. https://doi.org/10.1016/b978-0-12-815581-3.00002-6

[195] Pathak, L., & Shah, K. (2019). Renewable energy resources, policies and gaps in BRICS countries and the global impact. *Frontiers in Energy*, 13(3), 506–521. https://doi.org/10.1007/s11708-018-0601-z

[196] Since wheat and corn are the main feedstocks used for biofuels production in China and their prices are pushed higher due to the increase of demand, and this, as a result, affects the poor and net-food-purchasing urban and rural households., Dong, F. (2007). Food security and biofuels development: The case of china. In *Food and Agricultural Policy Research Institute (FAPRI) at Iowa State University, Food and Agricultural Policy Research Institute (FAPRI) Publications.*

account that, while the countries whose national policies we have already presented, are among the bigger biofuels' producers nowadays (See *Figure 5, Figure 6*), the EU has been playing just as important of a role. As well as ranking equally high in the biofuels' production scale, the EU promotes biofuels with sustainability-oriented policies, considered as severely driving the global biofuels' development.[197]

At EU level, biofuels are regulated and promoted mainly via Directives which, together, make up the greater *EU renewable energy policy* and which, in order to be enforceable in member states, must be implemented by domestic legislation. EU's "conversion" to biofuels has started with *Directive 2003/30/EC*[198] *on the promotion of the use of biofuels or other renewable fuels for transport,* where, according to *Article* 3§1 (a) *"Member states must ensure a minimum proportion of biofuels and other renewable fuels is placed on their markets, and, to that effect, shall set national indicative targets".* These targets for biofuels market penetration in member states were even more specified in provisions (b) (i) and (b) (ii) of the same *Article*, at 2% by the end of 2005 and 5.75% by the end of 2010 respectively.

However, in 2005 the 2% reference value for biofuels share in the transportation sector was missed,[199] and it became obvious that the 2010 goal would likely not be achieved either.[200] Soon, *Directive 2009/28/EC on renewable energy (RED)* was introduced, repealing the 2003 Directive, mandating in *Article 3§1* that *"at least a 20 % share of energy originates from renewable sources in the Community's gross final consumption of energy in 2020",* while, according to *§4 of the same Article: "Each Member State shall ensure that the share of energy from renewable sources in all forms of transport in 2020 is at least 10 % of the final consumption of energy in transport in that Member State"*.[201] Moreover, a 35% reduction of GHG emissions owing to the use of biofuels and bioliquids was described under the relevant provisions in *Article 17*, which would eventually reach at least 50 %, starting in 2017 and at least 60 % in 2018. It was also in 2009,

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[197] Stattman, S. L. (2019). *Biofuel governance in Brazil and the EU* (PhD Thesis). https://doi.org/10.18174/472916, Retrieved from https://research.wur.nl/en/publications/biofuel-governance-in-brazil-and-the-eu

[198] DIRECTIVE 2003/30/EC (2003). On the promotion of the use of biofuels or other renewable fuels for transport. European Parliament and the Council of the European Union. (2003). Retrieved from Europa.eu website: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32003 L0030

[199] Biofuels in the European Union A VISION FOR 2030 AND BEYOND Final draft report of the Biofuels Research Advisory Council. (2006). Retrieved from http://ec.europa.eu/research/energy/pdf/draft_vision_report_en.pdf

[200] Commission of the European Communities. (2008). Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources. Retrieved from https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM%3A2008%3A0019
%3AFIN% 3AEN%3APDF

[201] DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. (2009). Retrieved from Europa.eu website: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32009L0028

alongside the RED Directive, that *Directive 2009/30/EC* (or the Fuel Quality Directive, as it is known) was passed, providing for a reduction of GHG emissions caused by transport fuels by a minimum of 6% by 2020 (*Article 7a*).[202]

In the EU, promoting biofuel consumption is considered as a key point which will help achieve the Kyoto GHG emission targets set in 1997[203] and established for a second commitment period, which was also ratified by the EU.[204] Both the RED and the FQD Directives made references to the Kyoto Protocol and its importance, while they are both considered as the cornerstone for the regulation of the sustainability of biofuels. They both provided sustainability criteria for biofuels, which, besides the GHG emission reductions already mentioned, include (Under *RED, Article 17*) that feedstock used for biofuel production *"should not originate from land with high biodiversity value* or *land with high carbon stock* or *peatlands"* and that it should comply with agricultural and environmental requirements of *Council Regulation (EC) No 73/2009 of 19 January 2009*[205] (no longer in force), which set common rules and established support schemes for farmers under the *Common Agricultural Policy* (CAP). These criteria would have to be fulfilled in order for biofuels' producers to receive financial support.[206]

Even though, at that point and under the *RED Directive,* the potential impacts of indirect land use change (iLUC) were already mentioned (for example in *Article 18* were it is clear that the potential repercussions in GHG emissions must be taken into account), the first problems that came up almost immediately after the *RED* implementation, were linked to iLUC (biofuels whose feedstock is grown on existing arable land, while the demand for food and feed does not cease to exist, lead to increased food and feed production elsewhere, which in turn, may imply land use change (e.g. forests into agricultural land), thus causing the release of more CO2 into the atmosphere).[207] This is why in 2015, a new Directive came into force*, the (EU) 2015/1513 – iLUC Directive*,

[202] DIRECTIVE 2009/30/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009. (2009). Retrieved from Europa.eu website: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32009L0030

[203] Kyoto Protocol. (1997). Retrieved from Unfccc.int website: https://unfccc.int/kyoto-protocol-html-version

[204] EU to conclude ratification for second Kyoto Protocol commitment period by end of this year. (2017). Retrieved from Climate Action - European Commission website: https://ec.europa.eu/clima/news/eu-conclude-ratification-second-kyoto-protocol-commitment-period-end-year_en#:~:text=The%20Amendment%2C%20agreed%20in%202012

[205] Council Regulation (EC) No 73/2009 of 19 January 2009 establishing common rules for direct support schemes for farmers under the common agricultural policy and establishing certain support schemes for farmers, amending Regulations (EC) No 1290/2005, (EC) No 247/2006, (EC) No 378/2007 and repealing Regulation (EC) No 1782/2003. (2013). Retrieved from Europa.eu website: https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32009R0073

[206] Morone, P., Strzałkowski, A., & Tani, A. (2020). Biofuel transitions: An overview of regulations and standards for a more sustainable framework. *Biofuels for a More Sustainable Future*, 21–46. https://doi.org/10.1016/b978-0-12-815581-3.00002-6

[207] Memo on Indirect Land Use Change (ILUC). (2012). Retrieved from European Commission website: https://ec.europa.eu/commission/presscorner/detail/en/MEMO_12_787

amending the RED and the FQD, so as to reduce potential risks of indirect land use change and to promote the transition to advanced biofuels. The amendment limited the share of biofuels, originating from feedstock grown in arable land, that can be counted for the aforementioned 2020 targets, to 7%, adding a relevant provision in the original *Article 3-RED.*[208]

Still, uncertainty surrounding the biofuels' field continued to exist, and sustainability concerns kept rising, especially linked to conventional, first-generation biofuels, which continue to dominate in the biofuels market. EU had made significant progress in achieving energy efficiency, renewable energy was actively promoted while CO2 emissions had been noted to reduce,[209] however capping conventional biofuels seemed like a path that should be pursued more actively. In that direction, and in an attempt to reinforce the use of renewables, the *RED* was revised in 2018, with *Directive (EU) 2018/2001*, also known as *RED II,* coming into force,[210] raising in *Article 1§3* the overall EU target for renewables consumption to 32% by 2030, with a binding effect for all member states. Moreover, according to *Article 25§1, "each Member State shall set an obligation on fuel suppliers to ensure that the share of renewable energy within the final consumption of energy in the transport sector is at least 14 % by 2030 (minimum share)*".

Sustainability and GHG emission criteria are reformulated compared to the original *RED*, and biofuels and bioliquids used in transport must comply with them, to be counted for the *14% target* mentioned above, and be eligible for financial support (*Article 29, RED II)*. ILUC is also addressed in *RED II,* where in *Article 26* limits are provided for high iLUC-risk biofuels, affecting the volumes of these fuels that Member States can count for the fulfillment of their national renewable targets, at the same time introducing an exemption for biofuels certified as low iLUC-risk. Finally, it is important to highlight the fact that, within the 14% transport sub target, there is a dedicated target for advanced biofuels produced from feedstocks listed in *Part A of Annex IX*.

In addition to the above policies, there are several private voluntary schemes that assure biofuels sustainability, which take into consideration additional sustainability aspects to

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[208] DIRECTIVE (EU) 2015/1513 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 9 September 2015 amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources. (2015). Retrieved from Europa.eu website: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32015L1513
[209] European Union 2020 – Analysis. (n.d.). Retrieved from IEA website: https://www.iea.org/reports/european-union-2020
[210] DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the promotion of the use of energy from renewable sources. (2018). Retrieved from Europa.eu website: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX %3A32018L2001

the ones introduced with *RED II,* such as soil, water, air protection and even social aspects, and which are recognized by the European Commission as valid.[211]

[211] Voluntary schemes. (n.d.). Retrieved from Energy - European Commission website: https://ec.europa.eu/energy/topics/renewable-energy/biofuels/voluntary-schemes_en

Chapter 5: Policies' assessment and the importance of a biofuels' ethical framework

In the Chapter that preceded, we presented that, with regards to the global biofuel context, relevant rules at the international level are rare and they touch aspects, on the one hand indissolubly linked to the biofuels governance, yet more general, such as sustainable development and GHG emissions reduction; the reality is that national and supranational biofuel policies dominate. In this Chapter we will attempt to compare the four biofuel policies already examined, these of the U.S., Brazil, China and the EU using sustainability as a criterion and after that, we will introduce ethical aspects in our discussion and insist on the importance of an ethical framework for biofuels.

5.1 Assessment of the previously presented policies.

In our effort to conclude whether the policies formed till the present day, and the associated legislation, have been efficient towards promoting sustainable biofuels, we first have to make some introductory remarks, regarding some challenges we will encounter in this attempt:

i. Sustainability does not have a global definition; on the contrary, it is interpreted differently,[212] with some describing it as a *"shared ethical belief",* [213] while others, as thoroughly analyzed under *Chapter 3,* focus on the three pillars of sustainability, at times adding even more dimensions. [214],[215],[216] The same applies to *sustainable development,* [217] but also other significant terms' definitions, which differ in different countries' legislations, thus making the attempt to *compare almost impossible*.[218]

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[212] Bond, A. J., & Morrison-Saunders, A. (2011). Re-evaluating Sustainability Assessment: Aligning the vision and the practice. *Environmental Impact Assessment Review*, 31(1), 1–7. https://doi.org/10.1016/j.eiar.2010.01.007
[213] Seager, T. P., Melton, J., & Taylor Eighmy, T. (2004). Working towards sustainable science and engineering: introduction to the special issue on highway infrastructure. *Resources, Conservation and Recycling,* 42(3), 205–207. https://doi.org/10.1016/j.resconrec.2004.04.001
[214]O'Connor, M. (2006). The "Four Spheres" framework for sustainability. *Ecological Complexity*, 3(4), 285–292. https://doi.org/10.1016/j.ecocom.2007.02.002
[215] Nurse, K. (2006). Culture as the fourth pillar of sustainable development. *Small States: Economic Review and Basic Statistics*, 11, 28–40.
[216] Vos, R. O. (2007). Defining sustainability: a conceptual orientation. *Journal of Chemical Technology & Biotechnology*, 82(4), 334–339. https://doi.org/10.1002/jctb.1675
[217] Cloutier de Repentigny, P. (2016). The Sustainability of Biofuels: A Principled Lifecycle Assessment of the 2009 European Union Renewable Energy Directive and Its Framework. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2770198
[218] *Sustainability requirements for biofuels and biomass for energy in EU and US regulatory frameworks*. (n.d.). Retrieved from https://english.rvo.nl/sites/default/files/2013/12/Report%20EU%20and%20US%20biomass%20legislation%20-%20Partners%20for%20Innovation.pdf

ii. Local/regional values and meanings add another layer of complexity.[219] Different countries with different cultural backgrounds and different needs, with divergent definitions of "well-being",[220] also have different priorities and objectives with regards to biofuels' development; biofuels may be primarily promoted as replacements to conventional fuels but relevant policies frequently aim to fulfill other goals, among which, the most important ones appear to be a well-functioning national biofuels' market, small farmers support and agricultural promotion, and energy sovereignty.[221]

iii. The use of edible or non-edible feedstock -alone- is not an indicator of biofuels sustainability. As a matter of fact, sustainability should be assessed in each individual case, with regards to the production processes and land used for the feedstock but also with regards to the whole context, the whole system in which this production occurs, and taking into consideration besides environmental, also socioeconomic aspects. This leads to the conclusion that, for biofuels' expansion, knowledge from different fields must be implemented in the formation of policy, for potential risks to be minimized and eventual negative impacts to be avoided.[222]

5.1.1 Are existing policies and regulatory frameworks promoting truly sustainable biofuels?

Given the presentation of different policies around the world, under *Chapter 4* and the several complications related to biofuels' development, already mentioned in *Chapter 2,* it is obvious that biofuels, which have experienced a tremendous increase, principally due to government support, are equally surrounded by several concerns among which, indirect land use change, the competition with food production and loss of biodiversity.[223]

Starting with a general remark, we should pinpoint the fact that in the policies we presented, two type of biofuels are the ones mainly regulated, and thus predominantly used and produced: bioethanol and biodiesel. The U.S., Brazil and China are the top bioethanol producers globally, while the EU is the leader in biodiesel production (HVO

[219] Sala, S., Farioli, F., & Zamagni, A. (2012). Progress in sustainability science: lessons learnt from current methodologies for sustainability assessment: Part 1. *The International Journal of Life Cycle Assessment*, 18(9), 1653–1672. https://doi.org/10.1007/s11367-012-0508-6

[220]Tov, W. (2014). COMPARING WELL-BEING 2 The past decade has witnessed a growing interest in well-being indicators and their potential for informing public policy

[221] Von Braun, J. (2007). *Biofuels and the Poor: Finding the Win-Wins*. Retrieved from http://eeas.europa.eu/archives/docs/energy/events/biofuels/sessions/s4_05_von_braun_biofuels_poor_brussels_5-7-07.pdf

[222] Kulišić, B., B, A., & Dimitriou, I. (2019). *Sustainable landscape management for bioenergy and the bioeconomy - joint IEA bioenergy task 43 & FAO workshop*, October 2018.

[223] Morone, P., Strzałkowski, A., & Tani, A. (2020). Biofuel transitions: An overview of regulations and standards for a more sustainable framework. *Biofuels for a More Sustainable Future*, 21–46. https://doi.org/10.1016/b978-0-12-815581-3.00002-6

(Hydrotreated Vegetable Oil) biodiesel), as seen in *Figure 6.* However, even though the first three countries use different legislations for these two different alternative fuels, the EU has common legislative acts, which may rarely distinct between the two, but overall, it is in the ratio behind the legislation in which we can find that there is a differentiation; for example we could argue that biodiesel is substantially promoted on the basis that a reason that led to a peak in its development after 2015, was that the iLUC Directive of that year,[224] permitted that biofuels from waste oils and fats could be counted double for member states to reach the overall goals (The iLUC Directive amended *Article 3§4* of *RED (Directive 2009/28/EC)* with the addition of *point (f) in combination with ANNEX IX*).[225]

Starting the attempt to assess the policies, we will begin from the EU policy, in which, sustainability has been an ongoing and principal concern related to biofuels, with several changes having being made in the small period of active -mandatory- legislation (starting with the 2009 *Red Directive* milestone, which really changed the status quo). Nowadays the sustainability requirements for biofuels may be the stricter existing globally, with limits being implemented to raw material, which *must* originate from *renewable sources,* while the main aim is for feedstock from lands with high biodiversity or carbon stock to eventually be completely eliminated.[226] Simultaneously, standards have been set for the reduction of CO2 levels, compared to fossil fuels. Because of this stringent and innovative environmental legislation, the EU is being considered as a normative power[227] in environmental protection internationally.

In this direction -of the EU forming international sustainability standards for biofuels- we could add the following argument: as implied in previous chapters, sustainability requirements set at EU level for alternative fuels available in the European market*, apply equally* to biofuels and bioliquids *produced within the EU and to the ones imported from third countries*. This situation has been judged as beneficial for countries outside the EU, so as their biofuels will improve in terms of sustainability; on the other hand, this prerequisite has also been considered as a barrier for, mainly ethanol-producing

[224] Biodiesel Magazine - The Latest News and Data About Biodiesel Production. (2019). Retrieved from http://www.biodieselmagazine.com/articles/2516755/petroleum-companies-ramp-up-hvo-production-in-europe

[225] DIRECTIVE (EU) 2015/1513 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 9 September 2015 amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources. (2015). Retrieved from Europa.eu website: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32015L1513

[226] Renewable Energy – Recast to 2030 (RED II). (2018). Retrieved from EU Science Hub - European Commission website: https://ec.europa.eu/jrc/en/jec/renewable-energy-recast-2030-red-ii

[227] The term “normative power” for EU originated in 2002.
Manners, I. (2002). Normative Power Europe: A Contradiction in Terms? JCMS: *Journal of Common Market Studies*, 40(2), 235–258. https://doi.org/10.1111/1468-5965.00353

countries to import in the EU. With regards to Brazil, however, *Stattman, 2020*[228] argues that, the main problem could potentially arise with imports of Brazilian soybeans -and not ethanol- aimed for biofuel production, which are grown in highly biodiverse lands in the Brazilian savannah, and which would not fulfill the sustainability requirements to be imported in the EU.

When it comes to the feedstock used for production, it seems like all the policies we presented have been focusing on providing fiscal incentives for biofuels being produced from edible feedstock in the past, while in the recent years there has been a shift and these financial aids have been reconsidered and/or eliminated especially for conventional biofuels, while relevant subsidies or tax exemptions existing for *advanced biofuels*, have either stayed in place or been introduced. Till 2010, a large-scale production of second-generation biofuels had not been possible,[229] and, while this situation has changed in recent years, it is still a reality that biofuels originating from lignocellulosic material do not make up the largest amount of biofuels currently used and produced.[230] As stated in the *OECD-FAO Agricultural Outlook 2020-2029*, advanced feedstock is not expected to take a great part in biofuels production by 2029, while sugarcane and maize will continue dominating in ethanol production.

Besides the EU, which nowadays, as underlined above, has implemented limitations for traditional biofuels due to sustainability concerns, another country that has really pushed the transition from grains, sugarcane and vegetable oils to second-generation feedstock, has been the U.S. This happened through financing the development of second-generation technologies and setting notable targets for biofuel production from cellulosic sources – it was in the *RFS2* that that *advanced biofuels* were proclaimed as the way to achieve a decrease in GHG emissions (*See also 4.2.1 The U.S Policy).* When it comes to Brazil, national biofuel policies have not changed with regards to the type of raw material used for biofuels, but the main focus has been on the amelioration of conversion techniques for sugarcane and soy as feedstock.[231] On the contrary, China has suspended fiscal incentives and tax exemptions for edible crop-originating ethanol,

[228]Stattman, S. L. (2019). *Biofuel governance in Brazil and the EU* (PhD Thesis). https://doi.org/10.18174/472916, Retrieved from https://research.wur.nl/en/publications/biofuel-governance-in-brazil-and-the-eu
[229]Sorda, G., Banse, M., & Kemfert, C. (2010). An overview of biofuel policies across the world. *Energy Policy*, 38(11), 6977–6988. https://doi.org/10.1016/j.enpol.2010.06.066
[230] Biofuels | OECD-FAO Agricultural Outlook 2020-2029 | OECD iLibrary. (n.d.). Retrieved from https://www.oecd-ilibrary.org/sites/3aeb7be3-en/index.html?itemId=/content/component/3aeb7be3-en#section-d1e21123
[231]Stattman, S. L. (2019). *Biofuel governance in Brazil and the EU* (PhD Thesis). https://doi.org/10.18174/472916, Retrieved from https://research.wur.nl/en/publications/biofuel-governance-in-brazil-and-the-eu

maintaining subsidies and other favorable economic provisions only for other types of bioethanol.[232]

Overall, concerning the economic incentives for advanced biofuels production, governments, according to the *2019 Study* from IRENA (International Renewable Energy Agency) titled: *"Advanced biofuels: What holds them back"*, offer economic incentives most frequently to fuel producers and not feedstock suppliers – because if they did support suppliers directly they would risk prices and quantity of raw material to increase because of the demand- but in this way, merely an indirect support for farmers is not sufficient to make them adopt new crops and practices.[233]

That being said, we need to bear in mind that direct subsidies for farmers have also been part of the policies presented, since one of the most important drivers for biofuels development has been policy-makers' intention to support rural areas, a fact which confirms the existence of strong links between the *biofuel industry and agriculture.* It seems that an abolition of biofuels policies supporting feedstock grown in land (either edible or non-edible, so second-generation feedstock included), would possibly jeopardize, up to a point, support to farmers, and even cause some political consequences. Subsidies aimed at rural communities have also been criticized on the basis that, because of them, biofuels are "*an expensive form of GHG emissions reduction".*[234] In that sense, agriculture-centered provisions and fiscal incentives found in biofuel-promoting legislation could prove successful in supporting domestic farmers, but maybe not as efficient from an economic point of view, nor an environmental one, if we consider that, concerns for GHG emissions are relevant even for second-generation biofuels.[235] In Brazil, specifically, even the social parameter related to farmers support was criticized as insufficient, since current policy excludes smallholder farmers, not allowing them to participate in the biofuels development, thus aggravating social inequality and poverty.[236]

It is true that, in the last few years, motivation for biofuels expansion has not been focused only on climate change mitigation and energy security, but employment and rural

[232] Morone, P., Strzałkowski, A., & Tani, A. (2020). Biofuel transitions: An overview of regulations and standards for a more sustainable framework. *Biofuels for a More Sustainable Future*, 21–46. https://doi.org/10.1016/b978-0-12-815581-3.00002-6

[233] Advanced biofuels: What holds them back? (n.d.). Retrieved from https://www.irena.org/publications/2019/Nov/Advanced-biofuels-What-holds-them-back

[234] Mattioda, R. A., Tavares, D. R., Casela, J. L., & Junior, O. C. (2020). Social life cycle assessment of biofuel production. *Biofuels for a More Sustainable Future*, 255–271. https://doi.org/10.1016/b978-0-12-815581-3.00009-9

[235] Mohr, A., & Raman, S. (2013). Lessons from first generation biofuels and implications for the sustainability appraisal of second generation biofuels. *Energy Policy*, 63, 114–122. https://doi.org/10.1016/j.enpol.2013.08.033 .

[236] Sakai, P., Afionis, S., Favretto, N., Stringer, L. C., Ward, C., Sakai, M., … Afzal, N. (2020). Understanding the Implications of Alternative Bioenergy Crops to Support Smallholder Farmers in Brazil. *Sustainability*, 12(5), 2146. https://doi.org/10.3390/su12052146

development have also been introduced as significant drivers for biofuel-policy makers.[237] Although it is not arguable that social considerations have gradually emerged, strategic goals and most importantly the *independence from fossil fuels*, are the ones dominating.[238] Every policy, first and foremost, tries to achieve an increase in biofuels produced domestically so as to subsequently lower fossil fuel imports; according to *Huang et al. 2013*, a decrease in demand which will result from lower conventional oil imports, will mean a simultaneous decrease in oil's price at national level and thus will generate an economic advantage for national economy and consumers, while it will potentially lead to increasing petroleum consumption -and prices- abroad.[239]

We can realize, in this way, that substantial domestic biofuels' demand, led by policies promoting them, is fundamentally important from an economic point of view. Even though this expansion in the recent years has been *"ideologically"* promoted for environmental protection reasons, while it also was beneficial for each country's compliance with international environmental obligations (as the ones mentioned under *subchapter 4.1.1*), we cannot deny that economic reasons are still what primarily makes governments actively include biofuel policies in their national agendas. In these agendas, economic development is inarguably central, taking into account that the wellbeing and wealth of their citizens is of great importance, particularly in developing nations, where industrialisation in countries like China and Brazil has led a large portion of the population to poverty. So, biofuels establishment could "fuel" the economy, while it could also contribute to meeting the continuously increased energy needs.[240]

This potential led biofuels to be considered as a synonym to economic development, since not only is their expansion capable to create new jobs, but most crucially it is the path for energy sovereignty to be accomplished. In this way, oil imports will be reduced, independence from unstable foreign oil suppliers will cease to exist, and the national economy will not have to be faced with the increased oil prices.[241] At this point, we also should not avoid to mention, that biofuels have gradually become cost-competitive with

[237] Morone, P., Strzałkowski, A., & Tani, A. (2020). Biofuel transitions: An overview of regulations and standards for a more sustainable framework. *Biofuels for a More Sustainable Future*, 21–46. https://doi.org/10.1016/b978-0-12-815581-3.00002-6
[238] Lovett, J. C., Hards, S., Clancy, J., & Snell, C. (2011). Multiple objectives in biofuels sustainability policy. *Energy Environ. Sci.*, 4(2), 261–268. https://doi.org/10.1039/c0ee00041h
[239]Huang, H., Khanna, M., Önal, H., & Chen, X. (2013). Stacking low carbon policies on the renewable fuels standard: Economic and greenhouse gas implications. *Energy Policy*, 56, 5–15. https://doi.org/10.1016/j.enpol.2012.06.002
[240] Nuffield Council On Bioethics. (2011). *Biofuels: ethical issues*. London: Nuffield Council On Bioethics.
[241] Afionis, S., & Stringer, L. C. (2012). European Union leadership in biofuels regulation: Europe as a normative power? *Journal of Cleaner Production*, 32, 114–123. https://doi.org/10.1016/j.jclepro.2012.03.034

conventional fuels, due to the rapidly evolving production technologies surrounding their development.[242]

Taking all the above into consideration, we can understand the importance of biofuels for countries, whether they are developed or developing, and the reasons behind governments implementing favorable policies, regardless of the severe effects they have been proven to cause to the environment, which were noticed from the first years of their introduction.[243] More importantly, it becomes clear why countries avoid to impose limitations in biofuels development (and if they do so, these limitations are sparse -with the exception of the EU), even though their production and use, with the contemporary technology and feedstock used at large-scale, is doubtable to realistically contribute to GHG emissions reduction; considering their entire life cycle, biofuels could potentially produce more CO2 emissions than conventional fossil fuels.[244] Even the EU, with the optimistic environmental protection-oriented approach has been criticized[245] since, even these limitations in the production of biofuels that nowadays dominate in the market (conventional first- and second- generation biofuels) can have adverse effects in the economy (which is equally unwanted for the reasons that preceded).

We can summarize our sustainability-oriented assessment for policies, emphasizing on the fact that the economic component seems to be the most respected from policymakers, in the sense that it is prioritized when compared to the other two components, and that environmental protection issues are gradually taken more seriously into consideration, but the social aspect is the one mostly neglected. Even concerning the farmers' support provisions, which have as a driver social cohesion, when large-scale farming is established, then fewer jobs are created (as we have noted above for Brazil) and definitely a switch to more environmental sustainable third- and fourth- generation biofuels, will mean that these provisions, and thus the social-inclusion intention, will cease to exist.

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[242] Erickson, B., Lutt, E., & Winters, P. (2016). Can Biofuels Replace Fossil Fuels? *Consequences of Microbial Interactions with Hydrocarbons, Oils, and Lipids: Production of Fuels and Chemicals*, 1–19. https://doi.org/10.1007/978-3-319-31421-1_379-1

[243] Biofuels: prospects, risks and opportunities | FAO | Food and Agriculture Organization of the United Nations. (n.d.). Retrieved from www.fao.org website: http://www.fao.org/publications/sofa/2008/en/

[244] Callegari, A., Bolognesi, S., Cecconet, D., & Capodaglio, A. G. (2019). Production technologies, current role, and future prospects of biofuels feedstocks: A state-of-the-art review. *Critical Reviews in Environmental Science and Technology*, 50(4), 384–436. https://doi.org/10.1080/10643389. 2019.1629801

[245] Michalopoulos, S. (2019, December 12). Biofuel expert calls on EU to revisit RED II to avoid 'impetus of oil.' Retrieved from www.euractiv.com website: https://www.euractiv.com/section/agriculture-food/news/biofuel-expert-calls-on-eu-to-revisit-red-ii-to-avoid-impetus-of-oil/

5.2 Towards a Biofuels' Ethical Framework

Approaching biofuels governance from a sustainability perspective is important, and all the three pillars (the economic, the environmental and the social) should be considered in the formation of policies. However, sustainability comes with multiple challenges, the most important being that it does not have a universal definition, as it has been continuously underlined, and the effort to bring the three aspects of sustainability to a balance, could even be impossible, while it also comes with unwanted trade-offs. We can understand that policies which have been attempting to regulate biofuels sustainably have failed, and where policies fail, ethical principles must be taken into consideration.

In the biofuels field, ethical approaches have been, for the most part, overlooked, while economic-favorable technical "solutions" have gained the most attention, which, however, fail to provide a satisfying answer to the moral questions related to human-nature relationships.[246] In this way we are faced with a "disoriented" sustainability, dependent on standards which aim at altering the global market scene in order to provoke a "good behavior" rather than causing a radical change to cultural presuppositions related to the notion of "economic development" and focusing on questions related to moral obligations.[247] Scientists and ethicists have already tried to reflect upon this, but a robust ethical framework is yet to be developed.

The establishment of a moral framework is relevant not only in the attempt to assess the current status quo of biofuels development (led by the legal regimes regulating them), but is also necessary in the ever evolving biofuel-related technological context, where new developments and thus new regulating approaches to biofuels appear, and the related moral concerns that could potentially arise, should be comparably assessed to the moral issues that existed with pre-existing situation.[248]

i. The land vs biofuels and food vs biofuels debates

Ethical principles that have been suggested and introduced till the present moment, focus on the potential problems that biofuels expansion could bear on vulnerable

[246] Nelson, M. P. & Vucetich, J. A. (2012) Sustainability Science: Ethical Foundations and Emerging Challenges. *Nature Education Knowledge* 3(10):12
[247] Van Horn, G. (2013*). Ethics and Sustainability A Primer with Suggested Readings by Gavin Van Horn*. Retrieved from CENTER FOR HUMANS & NATURE website: https://iseethics.files.wordpress.com/2013/09/ethics_and_sustainability_primer.pdf
[248] Nuffield Council On Bioethics. (2011). *Biofuels: ethical issues*. London: Nuffield Council On Bioethics.

populations[249] and developing countries[250] or the probable breaches of human rights,[251] and consider that the environmental consequences of biofuels have already been mostly addressed through policies.[252] Furthermore, even regarding the "land vs biofuels" debate, a case in which environmental repercussions – linked to increased GHG emissions[253], [254] and biodiversity changes when natural habitats are converted to human-dominated croplands[255]- have been found to be profound, a problem more and more addressed by relevant legislations nowadays, an anthropocentric approach still dominates; experts address it from a human perspective as "the right to land" or "the right to property", bringing to the spotlight the imbalance of power between large investors and smallholders, with the latter being excluded from the ever-growing industrialized biofuels sector, and countries choosing to facilitate the access to land to (foreign) investors, thus eventually violating the small farmers "right to land". [256]

On the other hand, we cannot argue against a human-centred approach when it comes to the *food vs biofuels* ethical debate. Although a huge controversy exists related to whether and in what extent biofuels indeed affect human access to food,[257] via the deprivation of croplands for biofuels-intended feedstock and the consequent augmentation of food prices,[258] multiple studies[259] have been published, explaining the unintended outcomes for food security, which cannot be ignored; nor should the poverty impacts resulting from higher food prices, which could even lead to hunger,[260] for some more

[249] Von Braun, J. (2007). *Biofuels and the Poor: Finding the Win-Wins*. Retrieved from http://eeas.europa.eu/archives/docs/energy/events/biofuels/sessions/s4_05_von_braun_biofuels_poor_brussels_5-7-07.pdf

[250] Zentou, H., Rosli, Nurul Shafiqah, Wen, H., azeez, kafel, & Gomes, C. (2019). The viability of biofuels in developing countries: Successes, failures and challenges. *Iranian Journal of Chemistry & Chemical engineering- International English Edition*, 38.

[251] León-Moreta, M. (2011). Biofuels - A Threat to the Environment and Human Rights? An Analysis of the impact of the production of feedstock for agrofuels on the rights to water, land and food. *European Journal of Legal Studies*. Retrieved from http://hdl.handle.net/1814/18600

[252] Gonzalez, C. (2016). The Environmental Justice Implications of Biofuels. *UCLA J. Int'l L. Foreign Aff.*, 20, 229. Retrieved from https://digitalcommons.law.seattleu.edu/faculty/771

[253] Searchinger, T., Heimlich, R., Houghton, R. A., Dong, F., Elobeid, A., Fabiosa, J., … Yu, T.-H. (2008). Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change. *Science*, 319(5867), 1238–1240. https://doi.org/10.1126/science.1151861

[254] Fargione, J., Hill, J., Tilman, D., Polasky, S., & Hawthorne, P. (2008). Land Clearing and the Biofuel Carbon Debt. *Science*, 319(5867), 1235–1238. https://doi.org/10.1126/science.1152747

[255] Hansen, A., Defries, R., & Turner, W. (2004*). Land use change and biodiversity.* https://doi.org/10.1007/978-1-4020-2562-4_16

[256] León-Moreta, M. (2011). Biofuels - A Threat to the Environment and Human Rights? An Analysis of the impact of the production of feedstock for agrofuels on the rights to water, land and food. *European Journal of Legal Studies*. Retrieved from http://hdl.handle.net/1814/18600

[257] Prasad, S., & Ingle, A. P. (2019). Impacts of sustainable biofuels production from biomass. *Sustainable Bioenergy*, 327–346. https://doi.org/10.1016/b978-0-12-817654-2.00012-5

[258] Ajanovic, A. (2011). Biofuels versus food production: Does biofuels production increase food prices*? Energy*, 36(4), 2070–2076. https://doi.org/10.1016/j.energy.2010.05.019

[259] Hochman, G., Rajagopal, D., Timilsina, G. R., & Zilberman, D. (2014). Impacts of Biofuels on Food Prices. *The Impacts of Biofuels on the Economy, Environment, and Poverty*, 47–64. https://doi.org/10.1007/978-1-4939-0518-8_4

[260] Tenenbaum, D. J. (2008). Food vs. Fuel: Diversion of Crops Could Cause More Hunger. *Environmental Health Perspectives*, 116(6). https://doi.org/10.1289/ehp.116-a254

vulnerable populations. The same concerns could apply to water, given the inherent interdependence between biofuels and water consumption; water is a prerequisite for biofuels growth and, on the other hand energy is necessary for its extraction and transportation. In this regard, future increased production, combined with the increase in world's population will be a challenge for the management of water, especially if part of it will be required for energy production, when current scenarios expect future water scarcity.[261]

At this point, it is important to remember that the right to food and water have legal foundations[262] in *Article 55 (a) of the Charter of the United Nations*[263]: *"With a view to the creation of conditions of stability and well-being which are necessary for peaceful and friendly relations among nations based on respect for the principle of equal rights and self-determination of peoples, the United Nations shall promote: a. higher standards of living, full employment, and conditions of economic and social progress and development".* Moreover, *Article 11 § 1 of the ICESCR (International Covenant on Economic, Social and Cultural Rights)*[264] provides that: *"The States Parties to the present Covenant recognize the right of everyone to an adequate standard of living for himself and his family, including adequate food, clothing and housing, and to the continuous improvement of living conditions".*

In spite of most scholars agreeing that policies should be reformulated, considering potential violation of the human right to food, in *Araujo Enciso, Fellmann, Pérez Dominguez & Santini, 2016,* the researches presented results of a 10-years forward looking scenario and argued that even though a potential abolishment of biofuel policies would adversely impact biofuel prices, this would have only a negligible effect on the fluctuation of crop prices, and thus would not ensure global food security, since other competitive used of crops would remain a reality (such as industrial use, feed production).[265]

[261] Lago, C., Herrera, I., Caldés, N., & Lechón, Y. (2019). Nexus Bioenergy–Bioeconomy. *The Role of Bioenergy in the Bioeconomy*, 3–24. https://doi.org/10.1016/b978-0-12-813056-8.00001-7
[262] Ekardt, F., & Hyla, A. (2017). Human rights, the right to food, legal philosophy, and general principles of international law. *Archiv Fur Rechts- Und Sozialphilosophie*, 103, 221–238.
[263] *Charter of the United Nations*., (1945). Retrieved from https://www.un.org/en/charter-united-nations/
[264] OHCHR | International Covenant on Economic, Social and Cultural Rights. (1976). Retrieved from Ohchr.org website: https://www.ohchr.org/en/professionalinterest/pages/cescr.aspx
[265] Araujo Enciso, S. R., Fellmann, T., Pérez Dominguez, I., & Santini, F. (2016). Abolishing biofuel policies: Possible impacts on agricultural price levels, price variability and global food security. *Food Policy*, 61, 9–26. https://doi.org/10.1016/j.foodpol.2016.01.007

ii. Who will benefit from biofuels' expansion? The threat to developing countries.

The "right to food" and "the right to land" may be jeopardized by biofuel expansion, but the relevant impacts are more intense for vulnerable populations (mainly in developing countries).[266] The question whether developing countries indeed face more severe effects due to the rapid development of biofuels and the relevant national policies – in the OECD countries[267]- that support this expansion, brings to the forefront ethical dilemmas associated with the equal distribution of cost and benefits among countries. This dilemma is apposite to the biofuels context, where developing countries have been found to have a remarkable potential as important contributors to the global renewable capacity,[268] with great amounts of available lands, while more developed ones have started to be interested in acquiring these lands, which seem as ideal for biofuels production.[269] What this means for local populations is that their access to natural resources (fresh water) may be put at risk, while land will be concentrated to large investors at the expense of locals, whose interests and well-being will be at stake, in favor of the economic development of developed states; as highlighted before, biofuels are perceived as a great economic advantage for national economies.

Additionally, even though developing countries have a comparative advantage in biofuels production, due to available and -perceived as ideal for biofuel feedstock- land, they have been faced with discriminating trade practices[270] from developed nations, and thus restrictions regarding the extent to which they can benefit from the prosperous biofuels trade. Besides that, land use changes, as a result of the exploitation of native lands on the altar of biofuels development for the prosperity of foreign nations, could have effects on the local biodiversity and climate. If we take into account that developing countries are already characterized as the most sensitive to climate change,[271] we can understand the problems that may arise.

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[266] León-Moreta, M. (2011). Biofuels - A Threat to the Environment and Human Rights? An Analysis of the impact of the production of feedstock for agrofuels on the rights to water, land and food. *European Journal of Legal Studies*. Retrieved from http://hdl.handle.net/1814/18600

[267] de Gorter, H., Drabik, D., Just, D. R., & Kliauga, E. M. (2013). The impact of OECD biofuels policies on developing countries. *Agricultural Economics*, 44(4–5), 477–486. https://doi.org/10.1111/agec.12031

[268] Pathak, L., & Shah, K. (2019). Renewable energy resources, policies and gaps in BRICS countries and the global impact. *Frontiers in Energy*, 13(3), 506–521. https://doi.org/10.1007/s11708-018-0601-z

[269] Bartonova, E. (2012). The impacts of biofuel production in developing countries. Retrieved from Resilience website: https://www.resilience.org/stories/2012-03-01/impacts-biofuel-production-developing-countries/

[270] Nuffield Council On Bioethics. (2011). *Biofuels: ethical issues*. London: Nuffield Council On Bioethics.

[271] Global Affairs Canada - Affaires mondiales Canada. (2015). Climate change in developing countries. Retrieved from GAC website: https://www.international.gc.ca/world-monde/issues_development-enjeux_developpement/environmental_protection-protection_environnement/climate-climatiques.aspx?lang=eng

In this context, the *Rio Declaration*[272] is of relevance with Principle 7 providing: *"States shall cooperate in a spirit of global partnership to conserve, protect and restore the health and integrity of the Earth's ecosystem. In view of the different contributions to global environmental degradation, States have common but differentiated responsibilities. The developed countries acknowledge the responsibility that they bear in the international pursuit of sustainable development in view of the pressures their societies place on the global environment and of the technologies and financial resources they command"*, and calling for an international cooperation among states in the attempt to conserve the health of the earth ecosystem.

Finally, developing states should pay attention and try to promote policies that do not damage the local ecosystem, while developed nations should reassess the existing policies that have been proven damaging, as well as their trade policies, which should not limit the developing countries export potential.[273]

5.2.1 Why we should abandon the anthropocentric approach: The importance of deep ecology

After considering the points made under *i. The land vs biofuels and food vs biofuels debates*, we should emphasize on a specific aspect, fundamental in the ethical approach that preceded: anthropocentrism. Ethics in the biofuels field are, for the most part, approached in a way which puts human interests in the center and assesses policies on the basis that human needs are not entirely taken into consideration or/and fulfilled. It is true that the conservation of biodiversity and the prevention of GHG emissions have also been central in the ethical discourse surrounding biofuels, with the *Nuffield Council on Bioethics*[274] recognizing, in 2009, two relevant ethical principles: a) *"biofuels should be environmentally sustainable",* b) *"biofuels should contribute to a reduction of greenhouse gas emission"*. Even when it comes to this however, which at first glance seems like a genuine concern for the Earth, things are slightly different.

At this point, we should address this fundamental question: is human welfare the sole reason which motivates concern for the conservation of healthy ecosystems, or is there an inherent value of ecosystems? The answer to this question depicts cultural presumptions that are profoundly embedded in our modern society, and which tend to give precedence to human-favorable aspects. For biofuels, the question is whether humans

[272] Rio Declaration on Environment and Development. (1992). Retrieved from Cbd.int website: https://www.cbd.int/doc/ref/rio-declaration.shtml
[273] Nuffield Council On Bioethics. (2011). *Biofuels: ethical issues*. London: Nuffield Council On Bioethics.
[274] Nuffield Council On Bioethics. (2011). *Biofuels: ethical issues*. London: Nuffield Council On Bioethics.

fundamentally care for the health of the Earth and the effects that these alternative fuels could bear on it, or whether their distress is focused merely on the fact that eventual climate and biodiversity problems could limit the potential of specific lands to perpetually produce biofuels. The fact that human needs are prioritized, potentially at the expense of natural habitats, is a conclusion which is supported by the fact that policies do jeopardize the health of ecosystems for economic development.

It ultimately turns out that the main problem we still are faced with is our inappropriate relationship with nature, when we see natural habitats purely as a means to fulfill human needs, as something distinct to humankind. Given this, the only way to ensure that, in the case of conflict between human interests and non-human ones, policies will not benefit humans at the expense of, for instance, other organisms, is a non-anthropocentric ethics approach.[275] While human-centered concerns for the environment only aim to secure human well-being, biocentric concerns have as a fundamental objective to also protect non-human organisms and natural habitats holistically (of which humans are a part). In anthropocentrism, humans will potentially start acting in favor of the environment and adopting some pro-environmental behaviours, while biocentrism is oriented towards true environmentalism, regarding both values and behaviors.[276]

[275]Burchett, B., Kyle L. (2016). Anthropocentrism as Environmental Ethic (Doctoral Dissertation). http://dx.doi.org/10.13023/ETD.2016.259

[276] Rottman, J. (2014). Breaking down biocentrism: two distinct forms of moral concern for nature. *Frontiers in Psychology*, 5. https://doi.org/10.3389/fpsyg.2014.00905

Chapter 6: Conclusions/ Final Remarks

A main objective for most countries promoting biofuels has been the reduction of CO_2 emissions in the environment; in these 20 years of active biofuel expansion, however, it soon became obvious that biofuels constitute as much of a risk for climate change, as a solution. Indeed, it has been observed that CO_2 levels may increase due to biofuels production and consumption, rather than be eliminated, as it happens with first generation biofuels.[277] In that sense, it seems that the initial key assumption for this immense government-driven biofuel promotion, has been formed as following: *Biofuels, emerging from renewable sources, are by default sustainable.* However, after some years of active development in the field, it became obvious that multiple criteria must be met for biofuels to be characterized as sustainable and that only holistic approaches, taking into consideration several aspects and throughout the "life" of biofuels -beginning from the feedstock cultivation to the final consumption- must be taken into consideration.

Policies are central in the biofuels' discourse, since they are the ones guiding their expansion, and they should be *reformulated*, in order to regulate aspects of biofuels development that are currently associated with uncertainty; for example, scientists agree that there are still *knowledge gaps* when it comes to concerns related to the biofuel industry's impact to biodiversity.[278] Besides incorporating provisions that will identify "ideal" areas for feedstock cultivation where the ecosystem's diversity will not be at risk -the most suitable being existing agricultural lands, while sensitive areas such as forests, natural grasslands and peatlands must be avoided- legislations should also regulate more exhaustively the aspects related to the conflicts for land, following the European paradigm, which, however, can still be ameliorated. A parameter, which, for instance, new legislations should incorporate, is that of a potential intensification in land conflicts in the future, due to phenomena caused by climate change such as water scarcity, erosion and increased soil salinity; more extensive attention should also be given to social aspects providing clear provisions with regards to locals being displaced and losing access to their lands and potentially other resources (water), due to the biofuel industry.[279]

Along with land-assessment provisions, policies must also include water assessment considerations in the biofuels context, an issue which has not been examined thoroughly in current legislations, but which is equally important, given the fact that water scarcity

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[277] Gasparatos, A., Stromberg, P., & Takeuchi, K. (2013). Sustainability impacts of first-generation biofuels. *Animal Frontiers*, 3(2), 12–26. https://doi.org/10.2527/af.2013-0011
[278] Lago, C., Herrera, I., Caldés, N., & Lechón, Y. (2019). Nexus Bioenergy–Bioeconomy. *The Role of Bioenergy in the Bioeconomy*, 3–24. https://doi.org/10.1016/b978-0-12-813056-8.00001-7
[279] Lago, C., Herrera, I., Caldés, N., & Lechón, Y. (2019). Nexus Bioenergy–Bioeconomy. *The Role of Bioenergy in the Bioeconomy*, 3–24. https://doi.org/10.1016/b978-0-12-813056-8.00001-7

is also a great global challenge. Little attention has also been given to food security, even though most experts are in a consensus that food availability is directly affected by biofuels production. In the effort to address all of these problems, it seems that the adoption of "sufficiency" principle in resource consumption could be of relevance and this could be achieved by a shift to economic models that go beyond GDP growth- oriented economic development (which we have already criticized in the previous chapter), such as degrowth, focused on local development, with a simultaneous empowerment of smallholders, aiding them to "ascend" in the biofuel industry.

Recommendations:

We will finish the current discussion, with providing some key recommendations with regards to legislation and policies reformulations, which, could be beneficial in the overall sustainability of biofuels.

1) *Economic support for research and development (R&D)* for technology for advanced biofuels should be provided, in order to identify ways in which biofuels could contribute to the restoration of degraded land, better manage drainage basins, improve efficiency of production, use less natural resources (land, water) and lower the production cost. The evolution of biotechnology is also important for promoting marine biomass as biofuel feedstock, which has been proven to be efficient in terms of sustainability.

2) *The importance of coherence among different policy domains*. Various policy domains frame biofuel development (energy, environmental and climate protection, trade), however since different interests are at stake, negotiations among stakeholders could lead to different, and even conflicting trade-offs in each policy sector. The only way to ensure that biofuels will reach the different objectives set in different policies, is for clear guidelines to be created from governments in the policy-making process and different countries to try and create biofuel-specific regimes which integrate cross-sectoral concerns. It is in this way that agriculture will still be supported -while shifting away from crop-originating biofuels-, or that GHG emissions will be eliminated -while support for the transportation sector will remain strong.

and *The promotion of stakeholders' active involvement*. Besides politicians and policy-makers, the scientific community as well as NGOs should have an active role in the policy-making process. In this way, besides achieving a true transdisciplinary approach, individual groups' knowledge, opinions or propositions regarding some burning issues can also provide some insight for a better biofuel strategy. Simultaneously, at an international level, such an active inclusion of different stakeholders is important in order to design suitable solutions for small farmers in (mostly) developing countries, which, as mentioned elsewhere, are often at a disadvantage. This, bring us to the third point in our recommendation

3) *Equitable distribution of bioenergy-related costs and benefits.* Future initiatives should promote small-scale production, at local and regional levels, especially when it comes to developing countries, because in this way they can solve their oil dependency problem, conserve cheaper energy from locally available sources and accomplish an overall better well-being. Moreover, international cooperation should be encouraged in order for technological knowledge and skills to be shared among nations, and the more developed ones to fulfill their obligation, under the *Rio Declaration,* to support those countries at development stage. In this direction, more economic powerful states should not exploit third countries' arable lands for their national economic gain, at the expense of that country's economy and environment. Moreover, fair trade principles should be respected.

4) *The introduction of an international sustainability standard for biofuels*. As it has been highlighted under recommendations 2 and 3, there are different interests and conflicts between different actors and countries. We already proposed a more active participation on the stakeholders part, but a well-rounded global solution would be fully achieved only with the establishment of an international sustainability standard for biofuels production, which could be promoted, at UN level, for example. Such an initiative would mean that countries would have to adhere to the same criteria for assessing biofuel GHG emissions from their production to their consumption, that national policies would have to respect the same principles with regards to land-use changes and trade limitations, but also that human rights and social aspects would be considered and food and water security would be ultimately put in the center of attention, a parameter which current legislations fail to address. In this way, major biofuel producing countries, will have to abide by this international regime and not merely adhere only to their national monitoring systems.

5) *The importance of Degrowth in the effort to achieve sustainable development.* Through our conversation it became clear that even though environmental and social concerns related to biofuels development have alarmed scientists and policy-makers, after these promising alternative fuels did not prove as environmentally friendly as initially thought, states remain hesitant to entirely change their supporting systems, since these fuels are a clear economic advantage, in the era where oil is continuously depleting and its price is incessantly increasing. It seems that human societies are driven by economic growth and that sustainable development, as currently formed, has as a main

purpose economic development, at times at the expense of the other two pillars (social and environmental viability).

Abandoning the economic growth-centered model in the modern world and implementing degrowth, the anti-consumerism movement which suggests that societies' primary goal should not be economic development (in the increasing-the-GDP sense), but overall *well-being and happiness,* might be hard to implement, but would be a pioneering solution especially for the Global South. Such a shift, which will come with a reduction in material consumption and thus energy needs, would lead to better resource management and would readjust the exploitation of natural resources, to meet the Earth's limitations. This would be a truly sustainable solution in the environmentally stressed world we live in, where overproduction and overconsumption constantly aggravate the situation. In the case of developing countries, such distancing from the Western dominant capitalist model, to resource responsibility and efficiency, would lead to economic self-sufficiency, and overall well-being.

However, it is hard to accept the shift to degrowth, in Global North societies, where anthropocentrism is the dominant belief, embedded in western cultures; a different philosophical basis is necessary in order for societies to understand and actively pursue the shift to degrowth which will be beneficial for environmental health. Deep Ecology, the notion that all living beings have an inherent value, and that humans are just another component of the ecosystem without having a superior value to the other organisms, could be used as the ideological basis behind this societal restructure, since in that sense respecting the ecosystem is a fundamental moral value[280] and environmental health, if this philosophy is adopted, leads automatically to well-being.

Having presented the above, it is true that societies are far from achieving such a shift, and it is probable that the degrowth model will not be implemented soon (or at all). However, keeping this ideal as a guideline, legislation could progressively be reformulated in the effort to achieve a balance between human activities and the laws of nature. Ethics and cultural perceptions, inherent in human societies, are harder to change, and because of that, a reformulation in the human relation to the nature is less probable to be achieved in the next decades, even though efforts are increasing and hopes arise that human societies will eventually be restructured in accordance with deep ecology ideas. What can be achieved, however, and must in any case be pursued, is to reach the maximum "moral" result, *through* the current anthropocentric ethical guidelines. A new approach in biofuels' legislation, which takes full account of these ethical dilemmas, will

[280] Dalla Casa, G. (n.d.). Deep ecology as a philosophical basis of degrowth. Retrieved from https://www.degrowth.info/en/catalogue-entry/deep-ecology-as-a-philosophical-basis-of-degrowth/.

certainly have more positive results, that the current situation, and could perhaps bring us closer to the desired change towards biocentrism.

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